DEFENSE INFORMATION SYSTEMS AGENCY
JOINT INTEROPERABILITY AND ENGINEERING
ORGANIZATION (JIEO)
FORT MONMOUTH, NEW JERSEY 07703-5613

TUTORIAL ON

SET-UP AND COMMUNICATIONS DELAYS

FOR ALL

UHF SATCOM DAMA MODES OF OPERATION

JIEO REPORT
20 JUNE 1994

1/21/98

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Reference our 01/20/98 telephone discussion. The two requested publications are attached: Assessment of Options for Improving the 5-kHz UHF DAMA Waveform, 10 May 95; and Tutorial on Set-up and Communications Delays for All UHF SATCOM DAMA Modes of Operation, 20 Jun 94. The author (A. Pappas) places no restrictions o` the distribution ^f these publications.

If I can be of further help, let me know.

Bob

Bob Hager

FOREWORD

This briefing and tutorial have been prepared by the Joint Interoperability and Engineering Organization (JIEO), whose principal interest is to improve joint interoperability among command, control, communications, and intelligence (C3I) systems. JIEO prepared the tutorial in response to a Joint Staff direction to provide a fundamental discussion of principles, capabilities, and limitations of the voice services supported by ultra high frequency (UHF) demand-assigned multiple access (DAMA) systems. The user community's understanding of these areas will enable active participation in the definition of the DAMA management and control system. The briefing and tutorial were prepared by Andreas Pappas, Defense Information Systems Agency, Joint Interoperability and Enginneering Organization (JIEO), Fort Monmouth, New Jersey 07703-5613, Jim French, and Frank Grausso, LOGICON, 145 Wycroff Rd., Suite 301, Eatontown, NJ 07703-1842.

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DEFENSE INFORMATION SYSTEMS AGENCY
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BRIEFING ON

SET-UP AND COMMUNICATIONS DELAYS

FOR ALL

UHF SATCOM DAMA MODES OF OPERATION

(FINAL)

JIEO REPORT
23 JUNE 1994

1. BRIEFING COVER PAGE

This briefing has been prepared by the Joint Interoperability and Engineering Organization, whose principal interest is to improve joint interoperability among command, control, communications, and intelligence (C3I) systems. This briefing provides a fundamental presentation of ultra high frequency (UHF) satellite communications (SATCOM) demand-assigned multiple access (DAMA) principles, capabilities, and limitations in the area of providing voice services over UHF DAMA systems. The purpose of this briefing is to present the user community with operational procedures and expected communications delays inherent in the UHF SATCOM DAMA standards. The briefing also identifies a method for UHF DAMA resource allocation of 5-kHz and 25-kHz satellite channels operating in the DAMA modes, as defined in MIL-STD-188-182 and MIL-STD-188-183.

DISA/JIEO CENTER FOR STANDARDS (CFS)

UHF SATCOM DAMA

SET-UP AND COMMUNICATIONS DELAYS

20 JUNE 1994

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2. OVERVIEW

This briefing is divided into five parts. The first two parts are introductory and are fairly short. The first part states the objectives of the presentation. Next, the background is presented, leading up to the tasking to prepare this briefing by the Joint Staff. The last three parts are substantial and address the following areas:

- UHF DAMA SATCOM Concepts, Modes, and Voice Services. Provides a discussion of UHF SATCOM DAMA concepts and modes by using common non-technically oriented examples, and defines the various voice services supported by the DAMA standards.

- UHF DAMA Set-up and Communications Delays. Presents the user with set-up and communications delays for the defined voice services, and provides estimates of the expected delay for terminal set-up, call set-up, and waveform delays.

- Access and Allocation of UHF SATCOM Services. Describes the access and utilization procedures and their effects on user resource allocation.

UHF SATCOM STANDARDS OVERVIEW

- OBJECTIVES
- BACKGROUND
- REVIEW OF DAMA PRINCIPLES
- SET-UP AND COMMUNICATIONS DELAYS
- ACCESS AND RESOURCE ALLOCATION OF UHF SATCOM SERVICES

3. OBJECTIVES

The objective of this briefing is to address two specific requirements identified at the MILSATCOM Users Conference 93-1. These requirements are stated in a Joint staff tasking memorandum, Subject: Tasking Based on MILSATCOM Users Conference 93-1, dated 10 September 1993. Requirements (a) and (b) of that memorandum request that the following actions be taken:

- Identify voice services supported by the UHF DAMA standards (MIL-STD-188-181 through 183). Describe access and utilization procedures, and how they will affect user resource allocation.

- Develop a tutorial describing the call set-up and communications delays for all UHF DAMA modes of operation

This briefing presents the concept of UHF DAMA from both technical and layman's perspectives, provides information on the constraints of the two DAMA waveforms, and estimates the call set-up times and the magnitude of any communications delays for voice services. The major modes of voice service supported by the DAMA standards are identified, as well as a proposed method for allocating UHF SATCOM resources to user organizations.

The intent of presenting this information is to help users understand exactly what capabilities are available with DAMA. Users appear to be developing a fear that DAMA will lessen or limit their communications capability. This fear stems from hearing only the few drawbacks of DAMA without hearing the many benefits that it offers. The main purpose of this tutorial is to present the whole story, so that users will understand both sides of DAMA and will understand that by giving a little, they can get a great deal in return. They will also see that DAMA does not preclude any capability that they have today, but rather, it gives users many choices and options to satisfy their UHF SATCOM needs.

UHF SATCOM STANDARDS
OBJECTIVES

- ADDRESS TASKING MEMORANDUM, SUBJECT: TASKING BASED ON MILSATCOM USERS CONFERENCE 93-1
  - IDENTIFY VOICE SERVICES SUPPORTED BY UHF DAMA STANDARDS
  - PROVIDE TUTORIAL ON SET-UP AND COMMUNICATIONS DELAYS
  - DESCRIBE ACCESS AND UTILIZATION PROCEDURES AND THEIR EFFECT ON USER RESOURCE ALLOCATION

4. BACKGROUND

The relatively low operating frequency, low cost, ease of use, and operational flexibility of UHF SATCOM make it the only communications system (commercial or military) that can support certain long-haul tactical, contingency, and covert military operations. However, the UHF SATCOM constellation cannot simultaneously satisfy all user demands for service reflected in the MILSATCOM User Requirements Database. The current terminal design restricts efficient use of the UHF SATCOM system. Current access techniques are based on single net per transponder (SNPT) and dedicated allocation. Studies indicate that this method results in a limited number of user nets that can be supported by the satellite resources, and it introduces significant inefficiencies in channel use. For example, when a particular net assigned to a channel is not communicating, channel capacity is wasted.

To overcome the severe shortage of UHF SATCOM channels and this inefficient use, the Joint Chiefs of Staff (JCS) has issued a memorandum requiring all Services to transition to DAMA by the end of FY 96. As this transition point approaches, organizations are asking for more information on the new DAMA system and how its implementation is likely to affect them. Several organizations have studied the implementation standards and have become alarmed at projected call set-up times and communications delays that can occur when operating in the various DAMA modes. These concerns were voiced at the MILSATCOM Users Conference 93-1 and in several official messages to the JCS, which resulted in the issuance of a Joint Staff tasking memorandum, dated
10 September 1993. This briefing addresses several of the actions directed in that memorandum relating to set-up times, communications delays, and user resource allocation.

UHF SATCOM STANDARDS BACKGROUND

- DEMAND FOR UHF SATCOM HAS OUTGROWN CURRENT SYSTEM CAPABILITIES
- CURRENT METHOD OF OPERATION IS INEFFICIENT
- NEW DAMA STANDARDS DEFINE A SIGNIFICANTLY MORE EFFICIENT SYSTEM OF OPERATION
- JCS HAS DIRECTED IMPLEMENTATION OF UHF DAMA BY SEPT 1996
- MANY MISCONCEPTIONS EXIST:
  - *DAMA OPERATION*
  - COMMUNICATIONS AND SET-UP DELAYS
  - ALLOCATION OF RESOURCES
- JCS DIRECTED JIEO TO PREPARE A TUTORIAL ADDRESSING THESE ISSUES

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5. UHF SATCOM DAMA PRINCIPLES

This part of the briefing presents UHF SATCOM concepts and modes supported by the DAMA standards, using common everyday examples to which a non-technically oriented user can relate. The various voice services provided by the DAMA standards are also defined.

To most users, the term *DAMA* conjures up a host of negative traits concerning an unfamiliar method of changing how they will access UHF SATCOM services. When anything is unfamiliar and new, there is always a fear that something will be lost or sacrificed in the name of progress. This fear is really spawned from not knowing all of the details about a change for the better, and that is exactly our objective of this briefing.

Although DAMA standards define new radio waveforms for operation on the UHF SATCOM channels that employ a technology called *time-division multiple access (TDMA)*, most users do not realize that not all of the UHF SATCOM channels are required to operate with this waveform. The DAMA standards include provisions for operating in three different modes, as follows:

- <u>Dedicated-Channel Single Access</u> - The current practice of assigning a user net exclusive rights to communicate on the dedicated channel.
- <u>Demand-Assigned Single Access (DASA)</u> - Operation on a single channel, requested on demand (using either a 5- or 25-kHz channel only when it is needed) via the DAMA waveforms' control system (controller).
- <u>TDMA/DAMA</u> - Sharing 5- or 25-kHz channel resources on demand, using the new waveforms described in the standards.

By using the system control features of DAMA, the user community can get what it has today: the dedicated-channel single access, plus two other modes of operation that can substantially increase the number of users that can be served by the same SATCOM resources. DAMA provides more options for service. It does not take away capability.

UHF SATCOM STANDARDS
DAMA PRINCIPLES

- DAMA IS NOT DAMA ANYMORE!
  - ORIGINALLY THE USER'S PERCEPTION OF DAMA WAS OPERATING ALL CHANNELS IN PRESCRIBED FORMAT
  - IT APPEARED TOO RIGID TO MEET SPECIAL REQUIREMENTS
- DAMA HAS EVOLVED INTO A UHF SATCOM SERVICE CONCEPT
  - DEDICATED-CHANNEL SINGLE ACCESS (DCSA)
  - DEMAND-ASSIGNED SINGLE ACCESS (DASA)
  - DEMAND-ASSIGNED MULTIPLE ACCESS (TDMA/DAMA) - OLD PERCEPTION OF DAMA
- NEW DAMA CONCEPT CAPITALIZES ON SYSTEM CONTROL FEATURES OF THE ORIGINAL DAMA

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6. WHAT IS DAMA?

DAMA, a communications channel access and resource allocation technique, provides the dynamic sharing of one or more channels among many users or user networks. Thousands of satellite terminals, within the same satellite coverage area, may share the channels of one or more satellites. Worldwide multi-user SATCOM connectivity can be provided by using relay schemes between channels on adjacent satellites of the Department of Defense (DOD) UHF SATCOM constellation.

The concept of DAMA is very simple. Given a pool of resources that can be shared, such as UHF satellite channels, the channels can be assigned for use on demand -- thus, the term *demand assigned*. Since many users are able to share or access the channels, the system is said to have *multiple access*. Therefore, the term *DAMA* means that multiple users can have access to a pool of resources on demand, which translates in our case to UHF SATCOM assigned to users on demand. Channel capacity is not wasted when the particular net assigned to a channel is not communicating.

Besides improving the efficiency of space resources, DAMA provides efficient use of the terminal segment. DAMA satellite terminals can participate in multiple networks, because they can be designed with the ability to communicate on any of the UHF military satellite communications (MILSATCOM) channels, both 5- and 25-kHz.

DAMA is allocation of resources in real-time.

UHF SATCOM STANDARDS
DAMA PRINCIPLES:
"WHAT IS DAMA?"

- DAMA

DEMAND ASSIGNMENT

(USERS ARE ASSIGNED COMMUNICATIONS ON DEMAND; THEREFORE, SYSTEM IS MORE EFFICIENT)

→ D A → D A M A

MULTIPLE ACCESS

(ABILITY OF A SINGLE CHANNEL TO BE ACCESSED BY MULTIPLE USER NETS)

→ M A → D A M A

ALLOCATION IN REAL-TIME

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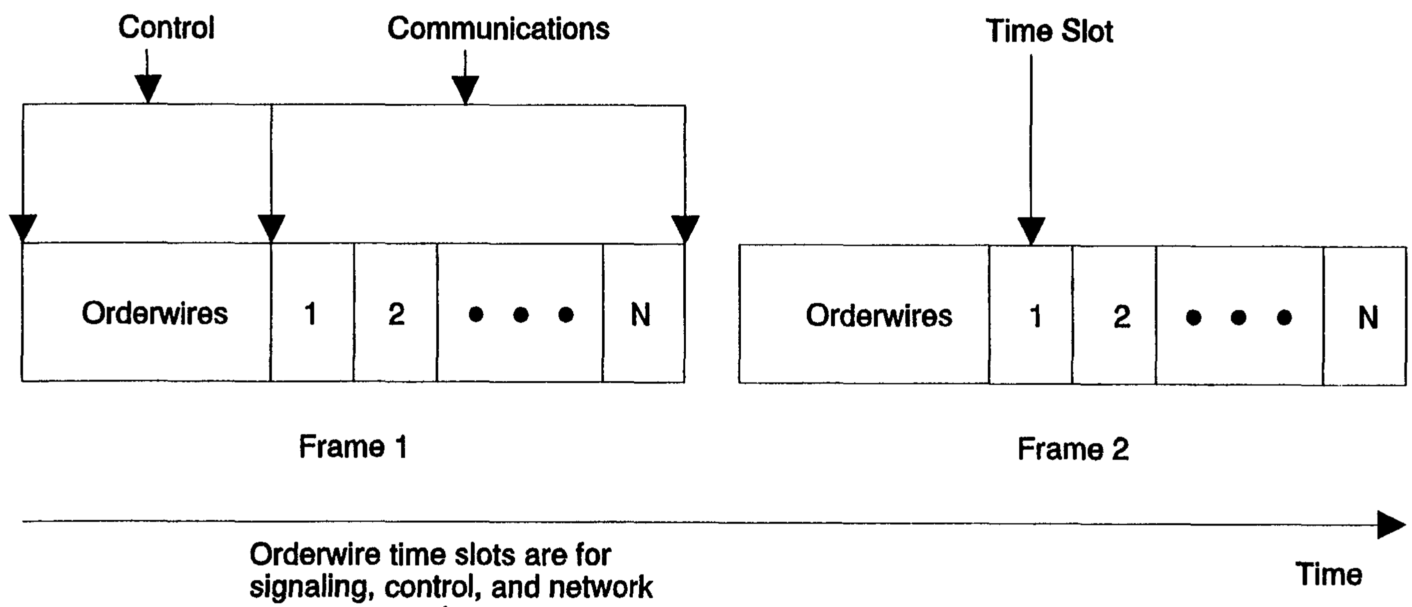
7. WHAT IS TDMA?

TDMA, a communications concept, permits many user nets to share a satellite channel. It is analogous to time-division multiplexing, in which one communications path is divided into time frames, which are further divided into time slots where data from each individual input is placed. With UHF satellite TDMA, each input can be considered a user who has been assigned a time slot. Using this multiple-access technique, a number of user terminals take turns transmitting bursts of data through a common transponder during their respective time slots. Thus, each earth terminal transmission has sole use of the transponder bandwidth and power during the duration of its time slot.

This slide illustrates two frames of a TDMA system. Two types of time slots are depicted. The first is the control time slot, in which orderwires carry signaling, control, and management information to control the system. The second is the communications time slot, in which users burst their information to communicate with other users.

UHF SATCOM STANDARDS
DAMA PRINCIPLES:
"WHAT IS TDMA?"

- TDMA
  - ANALOGOUS TO TIME-DIVISION MULTIPLEXING
  - ALLOWS MULTIPLE USERS TO SHARE A CHANNEL BY GIVING INDIVIDUAL USERS ACCESS TO THE ENTIRE CHANNEL FOR SPECIFIED AND SEQUENTIAL TIME INTERVALS (FRACTIONS OF A SECOND)



Orderwire time slots are for signaling, control, and network management data.

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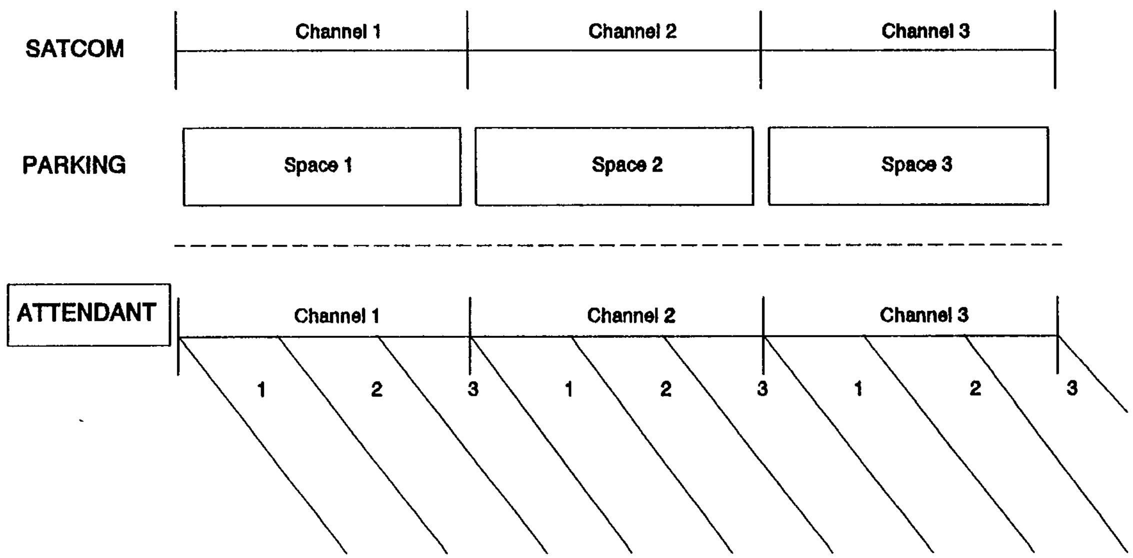
8. PARKING EXAMPLE TO ILLUSTRATE TDMA

To a non-technical person, the technical explanation of TDMA may have been confusing. Terms such as *multiplexing, frame, orderwire time slot*, and *communications time slot*, are totally unfamiliar terms. Let us deal first with multiplexing. Multiplexing is a method to get more from the same resources, or multiply a capability. A good example is parking places on a street. This slide illustrates two ways of using lineal curb space on a street for parking spaces. Parallel parking uses more lineal curb space per parking space than diagonal parking. Therefore, the diagonal parking method could be termed a "multiplexing" approach to conventional parallel parking. Notice, however, that we did not get something for nothing. To park more cars, we had to give up some of the width of the street. We had to make a tradeoff to park more cars, but if parking space is more scarce than street width, we live with a narrower street.

The slide illustrates that three cars can be parked in the same curb space as one parallel-parked car. We could call this space a *satellite channel* and have either one user in the space or three users in the space. If we decide to multiplex and use diagonal parking, each of the three spaces could be a frame with three time slots or user spaces. Now we really have to stretch to discuss the orderwire time slot. Suppose, instead of free parking, that every eighth frame we set up a parking attendant house in a diagonal parking space to control who parked where. The parking attendant and his house would take up a time slot but would control access to the parking spaces. The communications time slots are, of course, the parking spaces themselves.

With the UHF SATCOM TDMA waveforms, the amount of multiplexing that takes place compared to the parking example is much greater. Up to 20 users can be using the same satellite channel at the same time, depending on the type of service they are using (voice or data). We will continue to use the parking example as we examine the DAMA concept.

UHF SATCOM STANDARDS
DAMA PRINCIPLES:
PARKING EXAMPLE TO ILLUSTRATE TDMA



TDMA IS A MULTIPLEXING TECHNIQUE USED TO "MULTIPLY" THE NUMBER OF USERS THAT CAN USE A CHANNEL SIMULTANEOUSLY.

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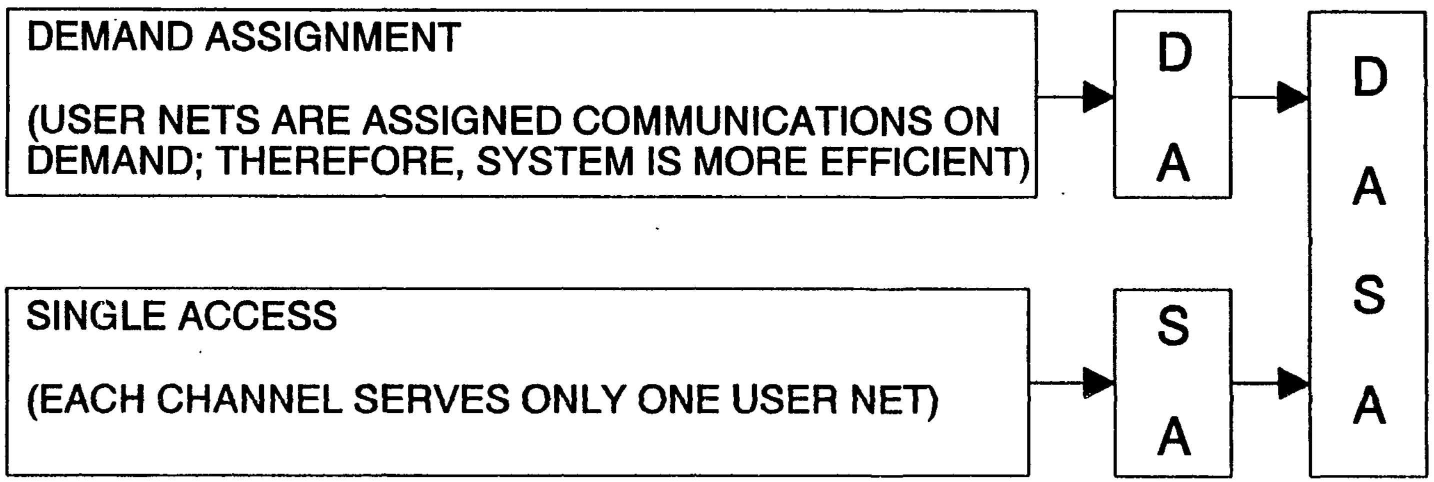
9. WHAT IS DASA?

DASA is simply assigning a net single, full channels on demand. This mode was added in the last revision of the DAMA standards to address problems of waveform delays within the TDMA/DAMA voice mode. This mode is implemented with a terminal operating in the DAMA waveforms. The next slide illustrates how it works.

UHF SATCOM STANDARDS
DAMA PRINCIPLES:
"WHAT IS DASA?"

- DASA



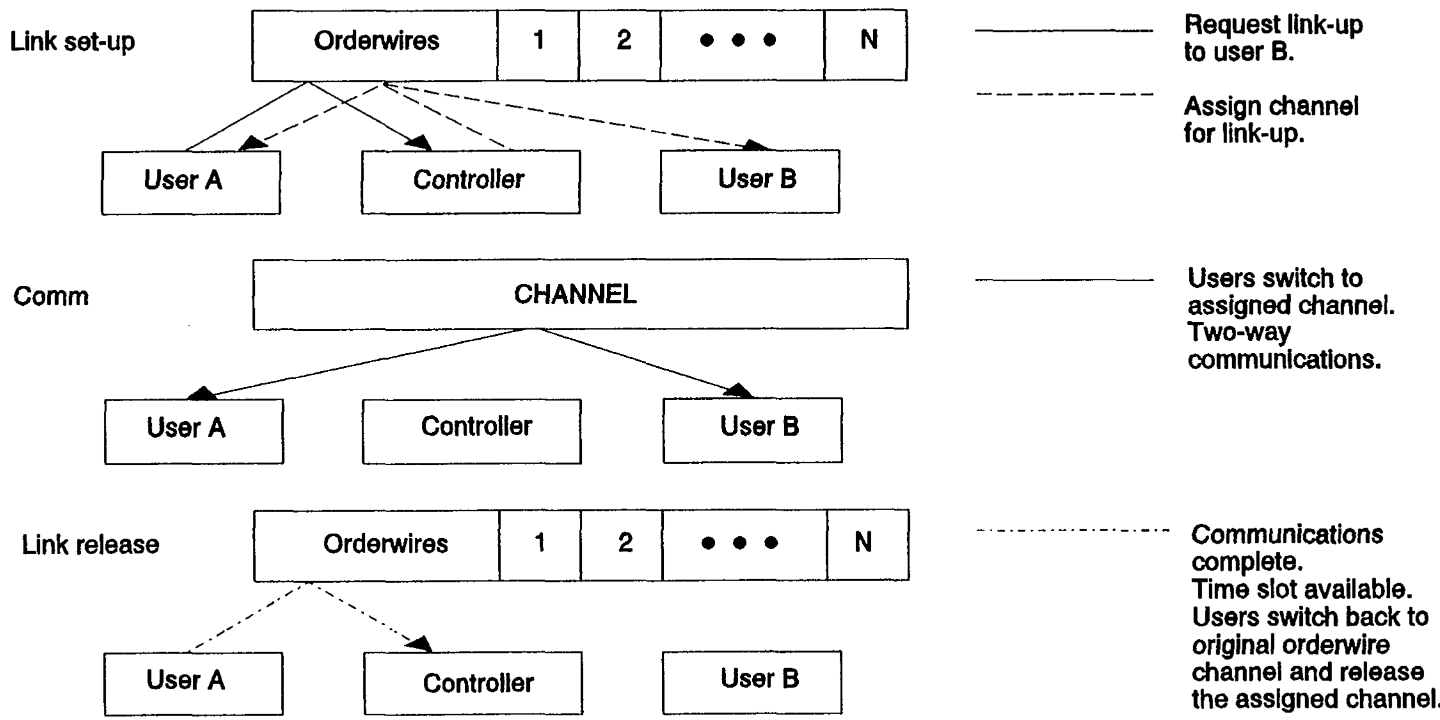
10. DEMAND-ASSIGNED SINGLE ACCESS

A request for a single channel is placed on the orderwire, and the controller assigns an idle channel (either 5- or 25-kHz, depending on bandwidth requirements, availability, or both). Next the communicating terminals receive the assignment over the control orderwire, switch to the assigned channel, and operate in the conventional mode on the assigned channel. When the communicating terminals are finished communicating, they switch back to the DAMA waveform, send a Call Complete message on the orderwire, and continue operating in the DAMA mode as usual. Essentially, this mode provides a dedicated channel for use by a net when needed. When they are not communicating, they release this channel for use by others who need it. If one considers that the average net uses a channel for 6 minutes an hour, and all nets usually do not talk at the same time, sharing channels significantly increases the number of nets that can get dedicated service when they need it. One drawback of this mode is that while a net is communicating on a DASA channel, orderwires are not received. Therefore, preemption of the circuit cannot be accomplished. This situation can be mitigated by limiting lower-priority users to a fixed amount of time to use the DASA channel, while always allowing priority 1 users unlimited use when they need it.

UHF SATCOM STANDARDS
DAMA PRINCIPLES:
DEMAND-ASSIGNMENT SINGLE ACCESS

- DASA (DEMAND ASSIGNMENT SINGLE ACCESS)

IN DASA, USER REQUESTS COMMUNICATIONS LINK-UP AND CONTROLLER ASSIGNS A FULL CHANNEL.
USERS RELEASE CHANNEL WHEN COMMUNICATIONS IS COMPLETE.



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11. WHAT IS TDMA/DAMA

TDMA/DAMA is simply assigning time slots to user nets on demand. As the slide illustrates, TDMA is used to allow more than one net share a single channel and provides the multiple-access portion. The time slots are assigned on demand, which accounts for the demand-assigned portion. This mode provides both the efficiencies of placing more than one user on the same satellite channel, as well as assignment of resources, only when they are needed. The next slide illustrates how TDMA/DAMA works.

UHF SATCOM STANDARDS
DAMA PRINCIPLES:
"WHAT IS TDMA/DAMA?"

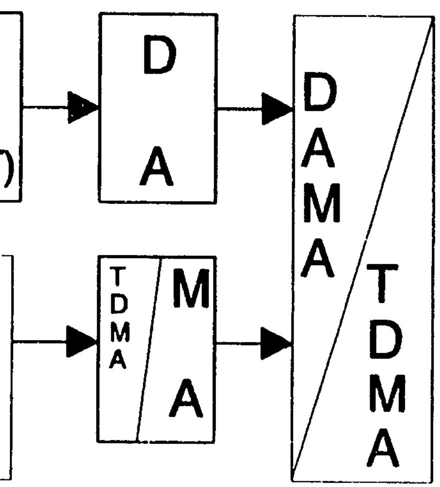
- TDMA/DAMA

DEMAND ASSIGNMENT

(USERS ARE ASSIGNED COMMUNICATIONS ON DEMAND; THEREFORE, SYSTEM IS MORE EFFICIENT)

MULTIPLE ACCESS

(ABILITY OF A SINGLE CHANNEL TO SERVICE MULTIPLE USER NETS AT THE SAME TIME, USING TDMA)



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12. TDMA/DAMA

This slide illustrates three phases associated with user communications using TDMA/DAMA on the UHF satellite network:

- Link set-up - User A requests a communications path to User B by sending an orderwire message to the controller. The controller assigns an idle time slot to the call and sends both User A and User B an orderwire message to use that time slot for communications

- Communications - User A communicates with User B on the assigned time slot for as long as they need the communications path.

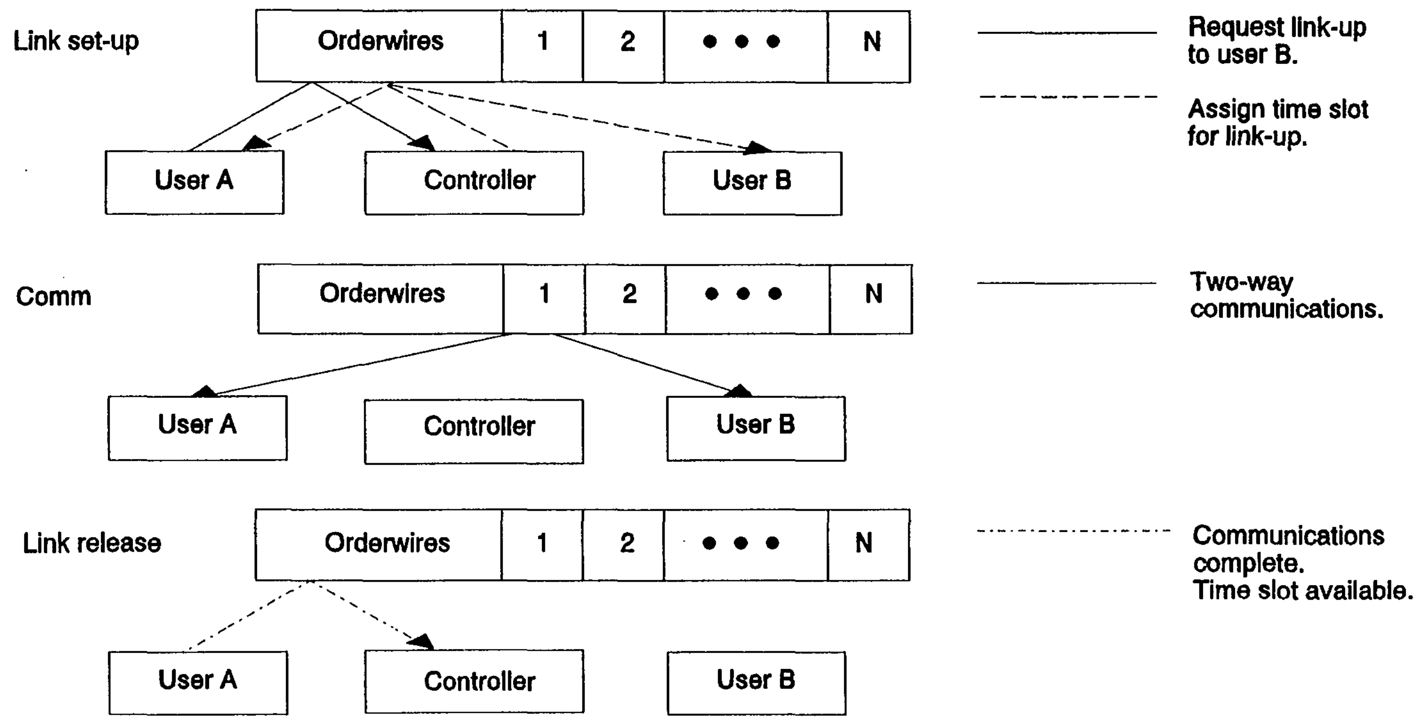
- Link release - When the communications between User A and B is completed, an orderwire message is sent to the controller indicating that the connection is no longer needed. The controller then makes the time slot available to accommodate other service requests.

Since there is a pool of channels, which can be divided into many communications paths (time slots), many users can be communicating simultaneously. And since all do not need to communicate at the same time, many more can be served than if each net of users were assigned a dedicated communications path.

UHF SATCOM STANDARDS
DAMA PRINCIPLES:
"WHAT IS TDMA/DAMA?"

- TDMA/DAMA

IN TDMA, USER REQUESTS COMMUNICATIONS LINK-UP AND CONTROLLER ASSIGNS TIME SLOT.
USERS RELEASE TIME SLOT WHEN COMMUNICATIONS IS COMPLETE.



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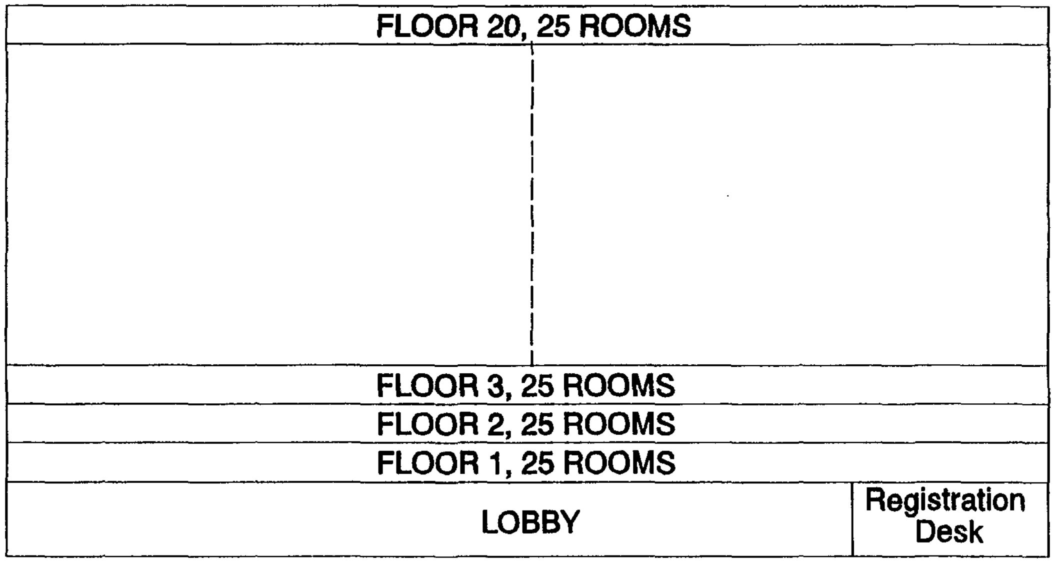
13. DAMA SERVICE CONCEPT EXAMPLE

To provide a simple analogy of the DAMA service concept of providing three different modes of operation, let us introduce another example and compare the DAMA concept to a large hotel. This hotel has 500 rooms on 20 floors with 25 rooms per floor. The hotel itself represents a satellite with 20 transponders (channels). Each floor of the hotel represents 1 of the satellite's transponders or channels. Since the channels can be divided into time slots for communications, the rooms on a floor represent communications time slots. The hotel registration desk represents the system controller. For the sake of time comparison, let us say that a day's stay at the hotel is equal to 1 minute of a UHF SATCOM communications duration. Having made these comparisons and representations, let us draw comparisons to using the space available in this hotel to the resources of a UHF SATCOM satellite.

UHF SATCOM STANDARDS: DAMA SERVICE CONCEPT EXAMPLE

- 500-ROOM HOTEL = 1 SATELLITE
- 20 FLOORS = 20 SATELLITE CHANNELS (TRANSPONDERS)
- 25 ROOMS PER FLOOR = 20 TIME SLOTS PER CHANNEL
- REGISTRATION DESK = SYSTEM CONTROLLER



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14. DEDICATED CHANNEL SINGLE ACCESS

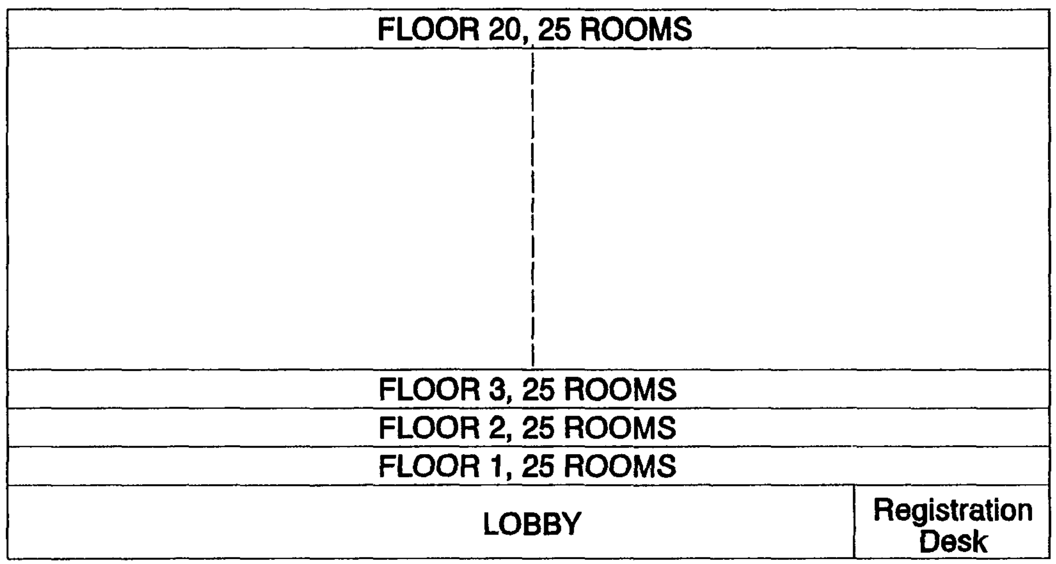
This mode of user allocation provides a single user net with an entire channel for the net's exclusive use. This is the single-net-per-channel (SNPC) method, as is currently done.

In the hotel example, an entire floor is set aside for one party for the entire year. We could represent this situation by assuming that whenever the President comes to this city, he stays at this hotel. The hotel sets aside an entire floor for him. For security purposes, *this floor is never used for any other purpose other than for the President's visits*, so that it remains secure and not used, even when he is not visiting this city. In this case, this floor serves only the needs of the President and no one else, whether he is there or not.

UHF SATCOM STANDARDS: DAMA SERVICE CONCEPT EXAMPLE

DEDICATED SINGLE-CHANNEL ACCESS

- A USER NET IS ASSIGNED DEDICATED USE (FULL-TIME) OF A SATELLITE CHANNEL
- A SPECIAL PARTY RENTS OUT AN ENTIRE FLOOR OF THE HOTEL FOR THE ENTIRE YEAR



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15. DEMAND-ASSIGNED SINGLE ACCESS

In this mode of resource allocation, a user net who needs a dedicated satellite channel requests the channel for a period of time. The controller assigns a channel for use by the net, and when the net is finished communicating, the channel is released for use by others.

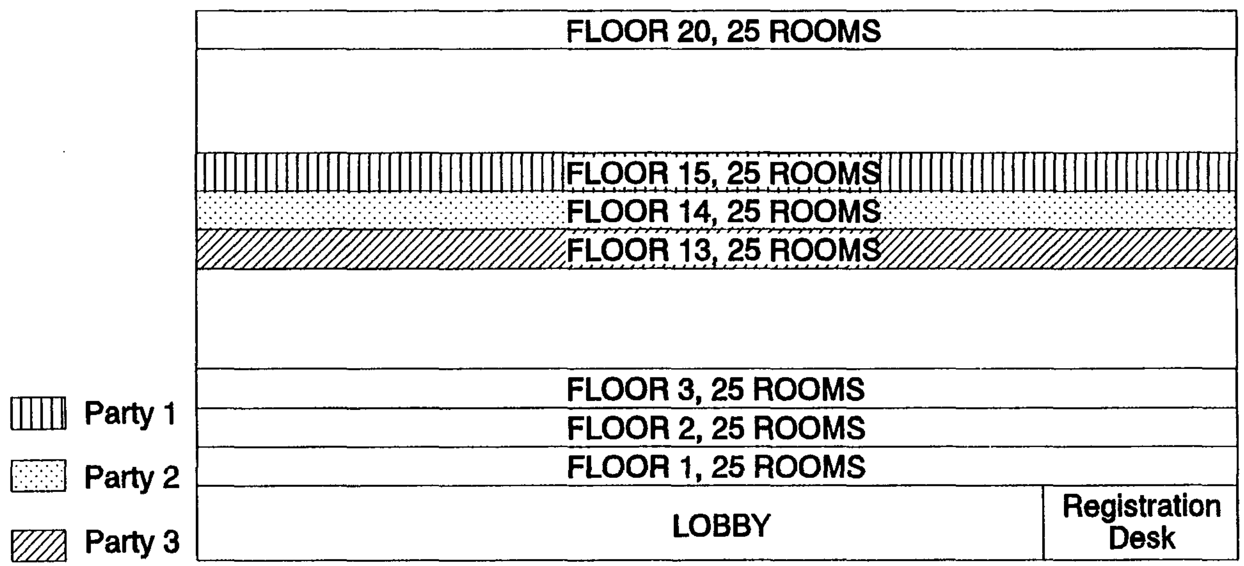
We can represent this situation by considering that various VIPs visit this city from time to time. When they are in town, they reserve an entire floor at the hotel for the number of days that they need it. To make these arrangements, reservations are made with the hotel registrar, who checks to make sure space is available during the requested stay. In this case, the hotel floor can accommodate more than one VIP party in a year. If each VIP wanted to stay a week, ideally, 52 different VIPs could use that floor during the year. That is certainly better use of an entire floor than we are getting from the President's dedicated floor.

UHF SATCOM STANDARDS: DAMA SERVICE CONCEPT EXAMPLE

DEMAND-ASSIGNED SINGLE ACCESS (DASA)

- A USER NET REQUESTS A DEDICATED CHANNEL FOR A FIXED PERIOD OF TIME WHEN HE NEEDS IT. THE CHANNEL IS RELEASED WHEN HE IS FINISHED.

- A PARTY RENTS AN ENTIRE FLOOR OF THE HOTEL FOR A BLOCK OF TIME WHEN THEY NEED IT. ANOTHER PARTY CAN RENT IT WHEN THEY ARE FINISHED WITH IT.



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16. TDMA/DEMAND-ASSIGNED MULTIPLE ACCESS

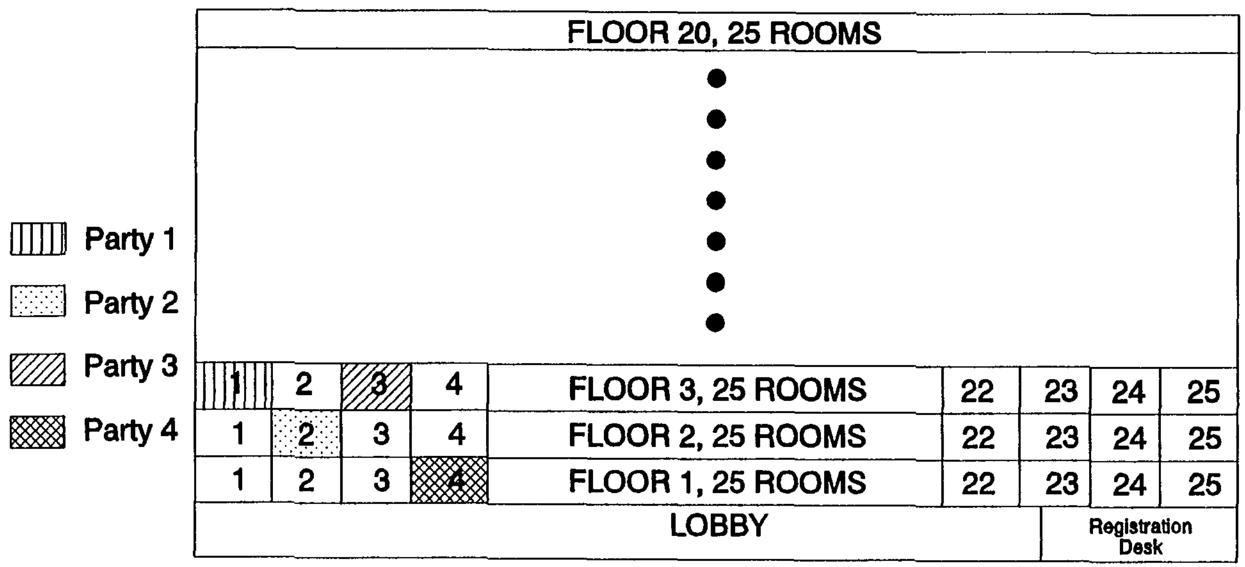
In this mode of resource allocation, a user net who needs a communications circuit requests the circuit for as long as it is needed. The controller assigns a time slot for use by the net, and when the net is finished communicating, the time slot is released for use by others.

In our hotel example, we can represent this mode by considering that when people are visiting this city on travel, they call ahead to the hotel registrar to reserve a room for their stay. The reservation system assures that they have sufficient space at the appropriate time for all people who have requested rooms. The rooms are used by a number of different people only when they need them. Under this plan, 25 different individuals can have rooms every night on each floor. Thousands of different people can be accommodated by 1 floor in an entire year. Tens of thousands of people can be accommodated by all the floors of the hotel in this mode of operation; however, let us remember, that we can still set aside the 1 floor for the President, we could set aside a couple of floors for visiting VIPs, and use the rest for the people who just need a room for a couple of nights. We can do it all simultaneously, and it is the same with the DAMA system. It is all a matter of configuring the resources to meet the requirements of the customers/users. We do this allocation of resources through the management and control system, which will be in charge of programming the system controllers that control access to the UHF SATCOM network.

UHF SATCOM STANDARDS: DAMA SERVICE CONCEPT EXAMPLE

TDMA/DEMAND-ASSIGNED MULTIPLE ACCESS

- A USER REQUESTS A TIME SLOT FOR AS LONG AS HE NEEDS TO COMMUNICATE. WHEN HE IS FINISHED WITH IT, IT IS RELEASED TO BE USED BY OTHERS.
- PARTIES REQUEST ROOMS FOR VARIOUS-LENGTH STAYS. WHEN THEY LEAVE, THE ROOM CAN ACCOMMODATE OTHER PARTIES.



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17. UHF SATCOM DAMA VOICE SERVICES

This slide defines the various voice services supported by the DAMA standards. The services are divided into three segments governed by the type of control orderwire from which services are assigned. For example, if a terminal is operating in the 25-kHz DAMA waveform, it is receiving and sending orderwires on its assigned "home channel." Some terminals will operate with 25-kHz home channels, while others will operate with 5-kHz DAMA on 5-kHz home channels. System control can direct any terminal to change its home channel, frequency band of operation, or both.

The 25-kHz orderwire offers 4 voice services. Two voice services are provided in the TDMA/DAMA mode through the assignment of either a 2.4-kbps or a 16-kbps time slot. Two voice services are provided in the DASA mode by assigning either a 5-kHz or a 25-kHz channel for either 2.4-kbps or 16-kbps voice, respectively.

The 5-kHz orderwire offers 3 voice services. One voice service is offered in the TDMA/DAMA mode by assigning a 2.4-kbps time slot. Two voice services are provided in the DASA mode by assigning either a 5-kHz or a 25-kHz channel for either 2.4-kbps or 16-kbps voice, respectively.

While terminals are communicating on the DASA channel, they do not receive any orderwires. This drawback results in the DAMA system's loss of preemption capability. The drawback is controlled by assigning terminals a time limit for use of the channel. The time limit is based on a user's priority.

Two voice services are available in the dedicated mode, which represents the manner in which channels are assigned today. Voice services can occur using either 2.4-kbps on a 5-kHz channel or 16-kbps on a 25-kHz channel. This mode can be implemented ahead of time or from the DAMA mode through assigning an indefinite-time-limit DASA channel.

UHF SATCOM STANDARDS
DAMA PRINCIPLES:
UHF SATCOM DAMA VOICE SERVICES

VOICE SERVICE NUMBER#	ORDERWIRE CHANNEL	VOICE SERVICE DATA RATE AND ACCESS
#1	25 kHz	2.4-kbps TIME SLOT ON A 25-kHz TDMA/DAMA
#2	25 kHz	16-kbps TIME SLOT ON A 25-kHz TDMA/DAMA
#3	25 kHz	2.4-kbps DASA ON A 5-kHz CHANNEL
#4	25 kHz	16-kbps DASA ON A 25-kHz CHANNEL
#5	5 kHz	2.4-kbps TIME SLOT ON A 5-kHz TDMA/DAMA
#6	5 kHz	2.4-kbps DASA ON A 5-kHz CHANNEL
#7	5 kHz	16-kbps DASA ON A 25-kHz CHANNEL
#8	NOT REQUIRED	2.4-kbps DEDICATED ON A 5-kHz CHANNEL
#9	NOT REQUIRED	16-kbps DEDICATED ON A 25-kHz CHANNEL

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18. UHF SATCOM DAMA SET-UP AND COMMUNICATIONS DELAYS:

TYPES OF DELAYS

The purpose of this part of the briefing is to present to the user the set-up and communications delays for the various voice services supported by the DAMA standards, and to provide estimates of the expected delays for each voice service. The delays are presented with respect to the steps that a user must logically take to establish communications over a UHF SATCOM link in the three different modes of DAMA operation. Below are the three categories of delays:

- <u>Terminal Set-up Delays</u> - The time it takes to set up the terminal to get ready to communicate.
- <u>Link Set-up Delays</u> - The time it takes to establish a communications path with a called user or net.
- <u>Waveform Delays</u> - The time delay associated with buffering the voice signals required to operate in the TDMA waveform.

The entries on the right side of the slide indicate which DAMA modes are subject to these delays.

TYPES OF DELAYS

	APPLIES TO:
• **TERMINAL SET-UP DELAYS**	
- TERMINAL INSTALLATION	(TDMA/DAMA, DASA, & DEDICATED)
- WAVEFORM ACQUISITION	(TDMA/DAMA, DASA)
• **LINK SET-UP DELAYS**	
- THE OPERATOR TELLING THE TERMINAL WHAT TYPE OF SERVICE IS REQUIRED	(TDMA/DAMA, DASA)
- TERMINAL ASKING THE CONTROLLER FOR ACCESS	(TDMA/DAMA, DASA)
• **WAVEFORM DELAYS**	
- TRANSMIT BUFFERING	(TDMA/DAMA ONLY)
- RECEIVE BUFFERING	(TDMA/DAMA ONLY)

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19. TERMINAL SET-UP DELAY

Terminal set-up delays consist of two elements: terminal installation and waveform acquisition. These delays can be viewed as those experienced between the time it is decided to install a terminal until the terminal is prepared to accept a user request for communications service.

Terminal installation delay is the time required to physically prepare the terminal for communicating. For a manpack terminal, this is the time required to remove the terminal from the pack, deploy and orient the antenna, connect all cables, turn the power on and warm up, and initialize the terminal. Based on information provided by UHF SATCOM users, during DAMA briefings, an average time to perform these actions is 4 to 5 minutes. Special Operations personnel have stated this can be reduced to 2-3 minutes, but, on the average, 4 to 5 minutes is typical.) This delay is not unique to the new waveforms being implemented, except for terminal initialization, which requires seconds to complete.

Waveform acquisition delay is the time required to synchronize with the TDMA waveform, which is essential to permit terminals to participate in the network. Synchronizing with the TDMA waveform requires frame acquisition and uplink timing. To request service, 5-kHz users must also login with the DAMA controller, and login takes a finite time to complete. The expected waveform acquisition delay for the 5-kHz waveform is a range of 27 to 36 seconds. The expected waveform acquisition delay for the 25-kHz waveform is a range of 1.5 to 12.7 seconds. These delays assume that there are no collisions (no terminals acquiring uplink timing at the same time) during this process. These waveform acquisition delays apply only to the TDMA/DAMA and DASA modes.

UHF SATCOM STANDARDS: DAMA SET-UP AND COMMUNICATIONS DELAYS

TERMINAL SET-UP DELAYS

- **INSTALLATION - AVERAGE 4-5 MINUTES**
  - ASSEMBLE
  - POSITION TERMINAL
  - POWER-UP

- **WAVEFORM ACQUISITION**
  - 5 kHz - ACQUIRE FRAME → UPLINK TIMING → LOG-IN → READY TO CALL
  - 25 kHz - ACQUIRE FRAME → UPLINK TIMING → READY TO CALL

- **EXPECTED WAVEFORM ACQUISITION DELAYS**
  - 5 kHz - 27 to 36 SECONDS
  - 25 kHz - 1.5 to 12.7 SECONDS

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20. LINK SET-UP DELAYS

This slide presents the delays experienced from the time a user initiates a request for service until the DAMA controller responds to the request by notifying the calling and called party of the resources allocated for the requested service. This delay is similar to dialing a telephone and waiting for an answer. Link set-up delays fall into two categories, defined as *operator/user entry* and *link signaling protocol delays*.

User input delay in initiating a service request when operating in the TDMA/DAMA and DASA modes is minimal but does take more time to complete than for communicating in the dedicated mode. For the dedicated mode, the handset is picked up, the called party is signaled, and talking begins. The only delay experienced in this case is the time required to initiate the signaling and the propagation time for the signal to travel over the satellite system, which is 238 milliseconds.

TDMA/DAMA and DASA operation require additional operator action to develop the circuit set-up request message. This message includes 10 separate entries by the operator for 5-kHz operations. The additional delay is only a few seconds. These delays apply to both 5- and 25-kHz DAMA operations. The standards have no control over this delay. However, the specifications for the terminals can include requirements for preset calling lists and other preprogramming options to reduce this delay.

Link set-up protocol delays are those associated with waiting for allocation of resources to communicate with another user, following initiation of a request for service. The delays experienced when requesting service using the DAMA orderwire system are determined primarily by the frame design and apply to TDMA/DAMA and DASA modes. Since the frame length of 5 kHz is 9 seconds, the link set-up delays are greater than for the 25 kHz, whose frame length is 1.4 seconds. The slide indicates a range of set-up times, based on the time when a request is initiated with respect to the frame timing. These delays are based on no collisions on the orderwires, meaning that terminals are not making requests for service at the same time.

UHF SATCOM STANDARDS: DAMA SET-UP AND COMMUNICATIONS DELAYS

LINK SET-UP DELAYS

- **USER INPUT TO TERMINAL**
  - TERMINAL DESIGN PROBLEM
  - PRE-SET CALL CONFIGURATIONS, ADDRESSES, AND MODES
- **LINK SET-UP TO PROTOCOLS**

REQUEST SENT → CONTROLLER RESPONSE → TERMINAL TALKS

- **LINK SET-UP DELAYS**
  - 5-kHz ORDERWIRE - 18 to 27 SECONDS
  - 25-kHz ORDERWIRE - 3.2 to 4.6 SECONDS

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21. WAVEFORM DELAY

Waveform delay is caused by the method by which information is sent over a TDMA system. Since there is not a continuous stream of information (bits) flowing over the network, but rather bursts of information during a time slot, to communicate over a TDMA system, a means to store information between bursts is required. This storage procedure is called *buffering*, and it works as illustrated in this slide. As a user is speaking into his handset, his voice is being converted into a bit stream at 2.4 kbps. If he is talking over a TDMA system with 4 time slots of 1-second duration, he gets to send his information for 1-second out of 4. Note that in the slide, 1 of the time slots in the frame is being used for orderwires. Before he can send, he must store the voice information, so that when his turn comes to transmit, he can send 4 seconds' worth of information in his 1 second interval. So he needs a storage device (buffer) that can store 4 seconds' worth of speech, which would be 4 times 2.4 kilobits (kb) or at least 9.6 kb. When his time comes up to send information, he must transmit everything in his buffer, which amounts to 9.6 kb. Therefore, for him to burst all of his information, he has to send at a transmission rate of 9.6 kbps during his time slot.

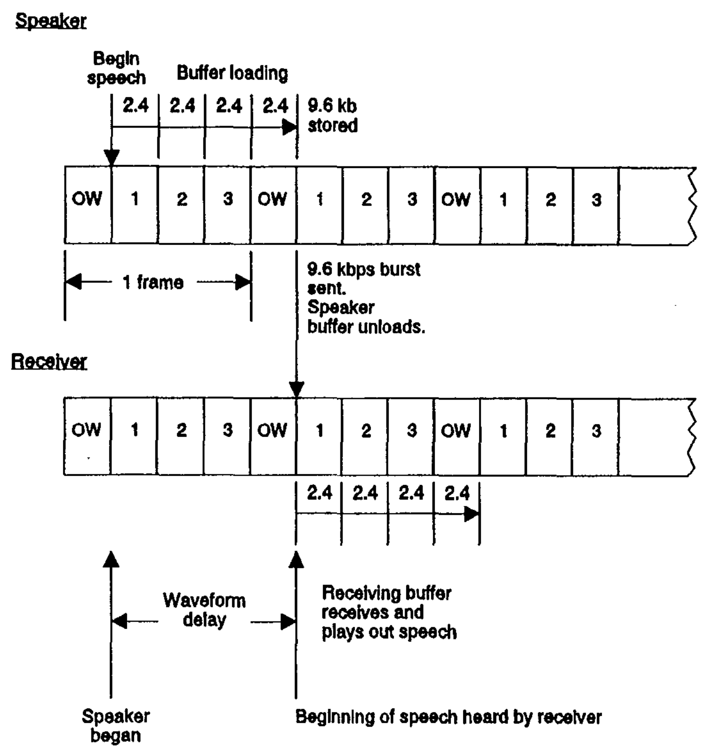
The effect of this buffering procedure causes what is known as *waveform delay*. The delay is equal to the length of the TDMA frame in our UHF SATCOM TDMA system. Therefore, the delay that would be experienced would be 4 seconds in our example. As the slide illustrates, the reason for the delay is that as a person is talking, his voice is being stored, to be transmitted at a later time in its respective time slot. The time it is stored before transmission is the length of the frame, at which time it is sent and received at the other terminal and played out through another buffer that received the burst of information sent during the time slot. Therefore, the receiver hears the voice of the speaker delayed by the length of 1 TDMA frame, which, in our example, is 4 seconds.

The waveform delay for 5-kHz channels is equal to its frame length, which is 9 seconds. The waveform delay for 25-kHz channels is 1.4 seconds, which is its frame length. It should be noted that the interactive voice delay -- the time from saying "Over" until a response is heard -- is twice the waveform delay. **This delay applies to voice services on TDMA/DAMA only.**

UHF SATCOM STANDARDS: DAMA SET-UP AND COMMUNICATIONS DELAYS

WAVEFORM DELAYS (TDMA/DAMA ONLY)

- TRANSMIT/RECEIVE BUFFERING



5 kHz - 9 seconds

25 kHz - 1.4 seconds

Legend:

OW - orderwire slots
1, 2, 3 - communications time slots

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22. UHF SATCOM DAMA VOICE SERVICES

This slide presents the results of the delays that will be experienced for the voice services defined in MIL-STDs 188-181/182/183. The voice service options available for both 5- and 25-kHz channels are presented with their associated set-up delays and waveform delays. The voice service options are for 2.4- or 16-kbps voice, as noted. Note that the length of the link set-up delays are based on which orderwire is being employed and results in a 6-fold decrease with use of the 25-kHz orderwire. The waveform delays on the other hand are determined by the waveform's being used for actual communications. The delays shown constitute the extra time required above the time experienced when operating in the dedicated mode, as is currently done. Transmission delay (earth terminal to satellite to earth terminal) and terminal installation times are not included in the slide. All delays have been rounded off to the nearest tenth of a second.

Based on the investigation of set-up and communications delays, it is not anticipated that high-priority users will ever be allocated 5-kHz TDMA/DAMA voice services, due to longer set-up and waveform delays inefficiencies introduced by providing voice services on the 5-kHz waveform. Due to the inefficiencies introduced by interfering with other low-speed circuit and message traffic, even low-priority users will not be assigned voice services on 5-kHz TDMA/DAMA unless no other resources are available. This policy will be formalized in MIL-STD-188-185, the DAMA Management and Control standard, which is now being developed.

UHF SATCOM STANDARDS

DAMA SET-UP AND COMMUNICATIONS DELAYS:

UHF SATCOM DAMA VOICE SERVICES

VOICE SERVICE NUMBER	ORDERWIRE CHANNEL	VOICE AND SERVICE DATA-RATE AND ACCESS	SET-UP DELAY NO COLLISIONS	WAVEFORM DELAY
#1	25 kHz	2.4-kbps TIME SLOT ON A 25-kHz TDMA/DAMA	4 TO 5 SECONDS	1.4 SECONDS
#2	25 kHz	16-kbps TIME SLOT ON A 25-kHz TDMA/DAMA	4 TO 5 SECONDS	1.4 SECONDS
#3	25 kHz	2.4-kbps DASA ON A 5-kHz CHANNEL	4 TO 5 SECONDS	0
#4	25 kHz	16-kbps DASA ON A 25-kHz CHANNEL	4 TO 5 SECONDS	0
#5	5 kHz	2.4-kbps TIME SLOT ON A 5-kHz TDMA/DAMA	20 TO 30 SECONDS	9 SECONDS
#6	5 kHz	2.4-kbps DASA ON A 5-kHz CHANNEL	20 TO 30 SECONDS	0
#7	5 kHz	16-kbps DASA ON A 25-kHz CHANNEL	20 TO 30 SECONDS	0
#8	NOT REQUIRED	2.4-kbps DEDICATED ON A 5-kHz CHANNEL	0	0
#9	NOT REQUIRED	16-kbps DEDICATED ON A 25-kHz CHANNEL	0	0

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23. ACCESS AND ALLOCATION OF UHF SATCOM RESOURCES

This part of the briefing presents the access utilization procedures and how they affect user resource allocation. It provides a brief overview of the UHF SATCOM DAMA management and control concept and a discussion of the problem of resource allocation for the DAMA system. A solution to this problem is proposed, using an apportionment method for allocating UHF SATCOM resources to user organizations. An example of the application of the apportionment method is presented.

After a study and several Joint working-group sessions, during which several alternative management and control concepts were evaluated and discussed, the Joint Staff directed JIEO to incorporate, into MIL-STD-188-185, a decentralized management and centralized system control concept. This direction was issued in a Joint Staff memorandum to JIEO, dated 24 November 1993.

The centralized system control and decentralized resource management concept entails having all UHF SATCOM channels in each footprint under one access system controller. The access system controllers for each footprint are tied together and connected to a central processing facility, which houses the management and control database. The access system controllers are under the jurisdiction of several authorities that provide management directions for the space segment resource allocation through their entries into their parts of the central database. All user nets for the CINCs, Services, and Agencies (C/S/A) gain access to the system via a central controller. The management functions, however, are performed by each organization's resource manager, who allocates services via priorities to users within the C/S/A organizations. The resource management functions are spread at different levels from the JCS level down to the unit level. As described in the Concept of Operations (CONOPS) for Management and Control of DAMA Systems, the entire satellite resources in a footprint will be represented as a "pie." JCS will allocate SATCOM services to the CINCs by apportioning to each CINC a piece of the SATCOM pie. The problem is "What is apportioned -- satellites, channels, time slots, etc?" Therefore, a method has to be devised to allocate a mixed set of DAMA services to users, which can be flexible and respond to rapid changes in mission requirements.

The problem is to allocate a mixed set of services, because in the real world, some users must have a dedicated channel, some will be happy with sharing a pool of dedicated channels (DASA), some will have their needs met by sharing time slots on the waveforms, and still others will be extremely grateful to get any kind of UHF SATCOM access at all. The logical solution to this problem is through the assignment of points for various types of SATCOM services. This system is called the point allocation system. The DAMA system is extremely flexible in its configuration and will be controlled by an overall management system that will be hierarchical from JCS to CINC to Service component to unit.

UHF SATCOM STANDARDS: ACCESS AND ALLOCATION OF UHF SATCOM RESOURCES

- JCS HAS SELECTED THE CENTRALIZED CONTROLLER AND DECENTRALIZED MANAGEMENT CONCEPT FOR DAMA
- DRAFT DAMA MANAGEMENT AND CONTROL CONOPS INCLUDES CONCEPT OF JCS's APPORTIONING "PIECES OF THE SATCOM PIE" TO CINCs
- A METHOD IS NEEDED TO ALLOCATE UHF DAMA RESOURCES TO USER ORGANIZATIONS
- PROBLEM OF ALLOCATION
  - DAMA IS A SERVICE CONCEPT
  - ALLOCATION OF SATELLITES, CHANNELS, OR TIME SLOTS IS NOT APPROPRIATE
  - MUST ACCOMMODATE A MIX OF SERVICES (DEDICATED, DASA, TDMA/DAMA)

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24. PROPOSED POINT ALLOCATION SYSTEM

The basis of this proposed concept is not to assign an organization a satellite, a channel, or a time slot for communications, but rather to allocate a number of service points to the organization. Points can be considered "money" for buying SATCOM services. The organization "spends" these points to buy the types of services it needs to satisfy its mission. With this method, each type of service is defined and assigned a point value. The point value represents the capacity subtracted from the total network capacity when a user selects it. The entire system has a total point capacity. Each satellite footprint has a total capacity of points that are color-coded. The color codes are required to permit the "purchase" of a mix of services on the two different DAMA waveforms. Four colors are used to represent the four basic resources:

5-kHz single-access channel
25-kHz single-access channel
5-kHz TDMA/DAMA
25-kHz TDMA/DAMA

The colors help distribute the services among the users and prevent any one particular resource from being oversubscribed. For example, if the points were not color-coded, nothing would prevent all users from purchasing all 5-kHz DASA channels, which could not be accommodated by the system.

The total number of points allocated to user organizations in this footprint cannot exceed the total point capacity, or services will be oversubscribed. Each footprint has 5,000 each of Green, Blue, Yellow, and Red points.

UHF SATCOM STANDARDS: ACCESS AND ALLOCATION OF UHF SATCOM RESOURCES POINT ALLOCATION SYSTEM

- EACH TYPE OF SATELLITE SERVICE IS ASSIGNED A POINT VALUE THAT REPRESENTS "ASSURED ACCESS" PRIORITY 1
- EACH SATELLITE FOOTPRINT HAS A TOTAL CAPACITY FOR PROVIDING ASSURED ACCESS EQUAL TO ITS TOTAL POINT VALUE
- POINTS ARE COLOR-CODED TO HELP DISTRIBUTE SERVICE AMONG 5-kHz AND 25-kHz TRANSPONDERS
- POINTS ARE ALLOCATED FROM JCS TO CINC TO COMPONENT TO UNIT
  - POINTS ARE LIKE "MONEY" TO "BUY" SERVICES
  - EACH ORGANIZATION HAS AN "ACCOUNT" WITH ALLOTTED POINTS
- EACH FOOTPRINT HAS 5,000 POINTS OF EACH COLOR POINT

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25. SAMPLE POINT ALLOCATION TABLE

This slide presents a sample table of point values for the various SATCOM services. The numbers in this table are based on some preliminary calculations as to the relative service capacities consumed from the total network when each service is selected.

The table lists the service number, the service offered, and the point and color value to "buy" that service. Each organization is allocated a number of colored points. Notice that some of the services can be bought only with Green points and others can be bought with any color points. It should also be noted that the services are not mutually exclusive; that is, if an organization buys a service, it is entitled access to that service and all services with an equal or lower point value. The point values represent those required to buy priority 1 service or "assured access" service.

Points allocated to an organization can be used by that organization and/or can be allocated to subordinate units for their use. For example, if an organization is assigned 1,000 Green points, and it decides to use 500 points to give one of its user nets with 1 DASA 25-kHz channel, that user net is also entitled access to services 2 through 10.

The organization might also use the remainder of the points to buy a 1.2-kbps circuit service and a 600-bps circuit service, and allocate 200 points to each of 2 subordinate units. Many other combinations of services exist that add up to 1,000 points. It depends on the number of user nets that the organization needs to satisfy, the type of services they require to complete their missions, and the number of subordinate units that they have to allocate SATCOM service. These nets are all priority 1 nets and have "assured access." Other user nets within the organization can be assigned service at a lower priority, as described in the next slide.

UHF SATCOM STANDARDS: ACCESS AND ALLOCATION OF UHF SATCOM RESOURCES, SAMPLE POINT ALLOCATION TABLE

- POINTS ARE FOR PRIORITY 1 "ASSURED ACCESS" SERVICE
- PRIORITIES 2-5 MAY ALSO BE SET UP, BUT THESE NETS WILL NOT HAVE "ASSURED ACCESS"

SERVICE #	UHF SATCOM SERVICE	POINTS
1	DASA ON 25-kHz CHANNEL	500 GREEN OR BLUE
2	DASA ON 5-kHz CHANNEL	200 GREEN ONLY
3	16-kbps CIRCUIT	350 GREEN OR BLUE
4	4.8-kbps CIRCUIT	200 GREEN OR BLUE
5	2.4-kbps CIRCUIT	90 GREEN, BLUE, OR YELLOW
6	1.2-kbps CIRCUIT	60 ANY COLOR POINTS
7	600-bps CIRCUIT	40 ANY COLOR POINTS
8	300-bps CIRCUIT	25 ANY COLOR POINTS
9	75-bps CIRCUIT	15 ANY COLOR POINTS
10	TDMA/DAMA MESSAGE SERVICE	10 ANY COLOR POINTS

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26. PROPOSED POINT ALLOCATION SYSTEM
PRIORITY MULTIPLIERS

To illustrate how precedence and preemption is integrated into the allocation concept, consider how one of the subordinate units can use its allocated points. As mentioned earlier, priority 1 users are those who will have assured access to SATCOM services. Other users in the unit are assigned lower-priority levels by taking the number of priority 1 points and applying a multiplier to calculate the number of points that can be assigned for that priority level. The multipliers serve two important purposes: (1) they force users to group their nets into separate groups with distinct priorities, rather than grouping them all in one priority, and (2) they allow users to access more expensive services on a lower-priority basis, which they otherwise would not be able to afford at all. Below are the multipliers:

Priority 1 - 1.00
Priority 2 - 1.25
Priority 3 - 1.50
Priority 4 - 2.50
Priority 5 - 5.00

Using this convention, the next slide provides an example of how a unit that was allocated 200 Green points can set up 19 nets, with 1 having "assured access" and the others at descending priority levels.

UHF SATCOM STANDARDS: ACCESS AND ALLOCATION OF UHF SATCOM RESOURCES SAMPLE POINT ALLOCATION TABLE

- **PRIORITY MULTIPLIERS**
  - PRIORITY 1 - 1.0
  - PRIORITY 2 - 1.25
  - PRIORITY 3 - 1.5
  - PRIORITY 4 - 2.5
  - PRIORITY 5 - 5.0
- **PRIORITY MULTIPLIER EXAMPLE**
  - AN ORGANIZATION HAS BEEN ALLOCATED 200 GREEN POINTS
  - THE UNIT CAN SET UP 19 NETS WITH 1 FOR "ASSURED ACCESS"

27. PRIORITY MULTIPLIER EXAMPLE

This unit is allocated 200 Green points. It decides to use those points to establish a priority 1 -- assured access net consisting of one 5-kHz DASA channel service, which equals exactly 200 Green points. To set up nets at lower-priority levels, it takes the 200 Green points and multiplies them by the appropriate multiplier, and establishes point values for priorities 2 through 5. The slide indicates the nets that this unit can set up at each of the priority levels.

This unit can set up 19 nets with SATCOM access, using the DAMA point allocation method. Under the old SNPC method, only 1 net has access. The DAMA system, coupled with this point allocation method, allows more users in this unit to access SATCOM services and still provides the priority 1 assured access net that would have been allotted under the old method. In addition, notice the vast range of services available to the other user nets. A priority 5 user net can get access to a full 25-kHz channel and send 16-kbps data during off-peak traffic hours (when least likely to get preempted); under the old system, there would not even be a chance for access to this type of service.

UHF SATCOM STANDARDS:
ACCESS AND ALLOCATION OF UHF SATCOM RESOURCES
POINT MULTIPLIER EXAMPLE

- **WITH 200 GREEN POINTS, THE FOLLOWING NETS CAN BE ESTABLISHED:**

  - PRIORITY 1 USER NETS (1 X 200 = 200 POINTS)
    ONE 5-kHz DASA CHANNEL SERVICE (200 POINTS)

  - PRIORITY 2 USER NETS (1.25 X 200 = 250 POINTS)
    TWO 2.4-kbps CIRCUIT SERVICE (180 POINTS)
    ONE 600-bps CIRCUIT SERVICE (40 POINTS)
    ONE 300-bps CIRCUIT SERVICE (25 POINTS)

  - PRIORITY 3 USER NETS(1.5 X 200 = 300 POINTS)
    TWO 2.4-kbps CIRCUIT SERVICE (180 POINTS)
    TWO 1.2-kbps CIRCUIT SERVICE (120 POINTS)

  - PRIORITY 4 USER NETS (2.5 X 200 = 1000 POINTS)
    ONE 25-kHz DASA CIRCUIT SERVICE (500 POINTS)
    FOUR 2.4-bps CIRCUIT SERVICE (360 POINTS)
    TWO 1.2-bps CIRCUIT SERVICE (120 POINTS)
    TWO 600-bps CIRCUIT SERVICE (80 POINTS)

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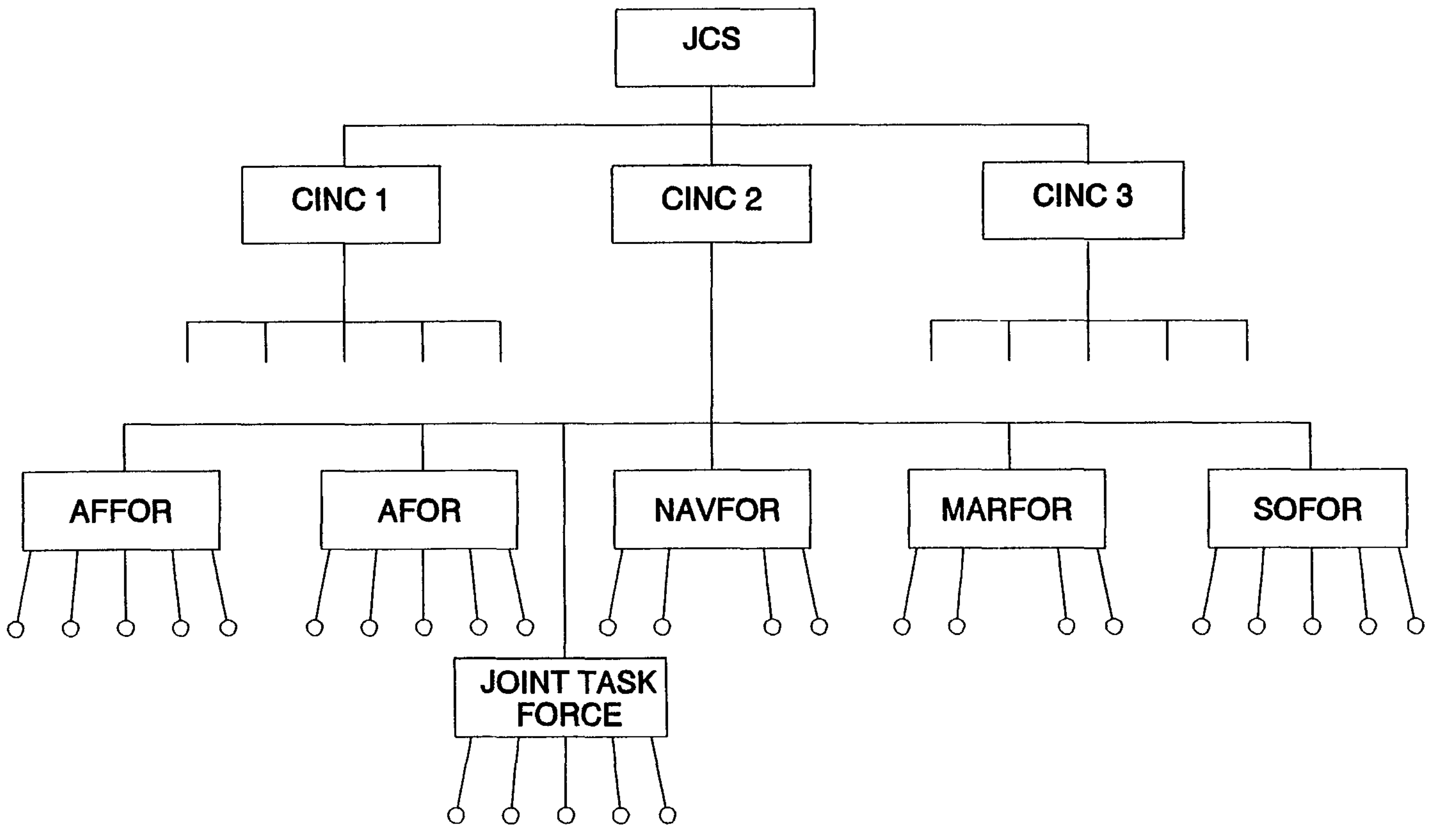
28. ALLOCATION EXAMPLE - SAMPLE ORGANIZATION

This part of the briefing presents an example of the proposed DAMA point allocation method. It illustrates the allocation of points from the JCS to the CINCs, from the CINCs to the component commands, and from the components to the units.

To illustrate the example, a representative sample organization was selected that is comprised of a satellite footprint with three CINCs, similar to the Indian Ocean area of operations. This slide presents the organizational structure from JCS through the CINC, component, and unit forces. To provide a generic organizational structure, we have labeled the three CINCs as 1, 2, and 3, and each CINC has 5 components with the option of a sixth joint task force (JTF).

UHF SATCOM STANDARDS: ACCESS AND ALLOCATION OF UHF SATCOM RESOURCES ALLOCATION EXAMPLE

SAMPLE ORGANIZATION



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29. JCS ALLOCATION AND DISTRIBUTION

Referring to the sample organizational structure, the JCS has 20,000 points (5,000 of each color) to allocate within this footprint. Each organization has an account and cannot spend more than is in that account. Point allocation adjustments can be negotiated with the allocating organization, and, therefore, trading of point resources can also be arranged so that subordinate elements can have their requirements met.

The JCS has a "UHF SATCOM service account" with 5,000 each of Blue, Green, Yellow, and Red points. The JCS will most likely hold points in reserve for special contingencies and assign a national command authority (NCA) net, which could include the White House, the JCS, and all of the CINCs in the footprint. This net would likely be a 25-kHz DASA channel. The remaining points would be allocated to the CINCs. Therefore, if the JCS were to keep 10% of the points in reserve and set up the NCA net, and then allocate to the CINCs the rest of the points, the JCS account would look like the one presented in this slide.

Note that in addition to the 500 points of each color held in reserve by the JCS, nets of lower priority can be set up using the 500 Green points assigned as priority 1. The points available for assignment in other priorities are Green points of 625 priority 2, of 750 priority 3, of 1,250 priority 4, and of 2,500 priority 5.

UHF SATCOM STANDARDS:
ACCESS AND ALLOCATION OF UHF SATCOM RESOURCES
JCS ALLOCATION AND DISTRIBUTION

- **JCS HAS ALL THE POINTS FOR THIS FOOTPRINT**
  - ONE NCA NET IS SET UP USING 500 BLUE POINTS
  - 10% OF POINTS ARE HELD IN RESERVE
  - REMAINDER OF POINTS ARE ALLOCATED TO THE CINCs
- **JCS CAN SET UP 500 BLUE POINTS' WORTH OF PRIORITY 2-5 NETS FOR LOWER-PRIORITY STAFF**
- **BELOW IS JCS's "UHF SATCOM ACCOUNT":**

ITEM	BLUE	GREEN	YELLOW	RED
INITIAL DEPOSIT	5,000	5,000	5,000	5,000
ONE 25-kHz DASA	-500	--	--	--
CINC1	-1,000	-1,000	-1,000	-1,000
CINC2	-1,500	-1,500	-1,500	-1,500
CINC3	-1,500	-1,500	-1,500	-1,500
BALANCE	500	500	500	500

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30. CINC2 ALLOCATION AND DISTRIBUTION

The allocation and distribution of CINC2's points will be used to continue the allocation example. CINC2 has 1,500 each of Blue, Green, Yellow, and Red points and will likely set up a command and control (C2) net, a component net, an NCA net, an intelligence (INTEL) net, and others as appropriate. The CINC may decide to set up his C2, component, and INTEL nets on a 5-kHz DASA channel, and his NCA net on a 25-kHz DASA channel. The CINC can then allocate the rest of his points to his subordinate components. CINC2's account is as presented in the slide.

CINC2 has 100 Green points in reserve. He can also assign to his support staff the following numbers of points in lower-priority services:

	BLUE	GREEN
Priority 2	625	750
Priority 3	750	900
Priority 4	1,250	1,500
Priority 5	2,500	3,000

The allocation of points continues with each component's assigning the nets that they require from their allocated points, and allocating the remainder to their subordinate units.

UHF SATCOM STANDARDS:
ACCESS AND ALLOCATION OF UHF SATCOM RESOURCES
CINC2 ALLOCATION AND DISTRIBUTION

- **CINC2**

  - SETS UP A COMMAND AND CONTROL (C2), A COMPONENT, AN NCA, AND AN INTEL NET
  - HOLDS 100 GREEN POINTS IN RESERVE
  - ALLOCATES THE REMAINDER TO HIS COMPONENTS

- **BELOW IS CINC2's "UHF SATCOM ACCOUNT":**

ITEM	BLUE	GREEN	YELLOW	RED
INITIAL DEPOSIT	1,500	1,500	1,500	1,500
ONE 25-kHz DASA	-500	--	--	--
THREE 5-kHz DASA	--	-600	--	--
AFFOR	--	-200	-300	-300
AFFOR	--	-200	-500	-300
NFOR	-500	--	-100	-300
MFOR		-200	-300	-300
SOFOR	-500	--	-300	-300
BALANCE	0	100	0	0

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31. AFOR'S POINT ALLOCATION AND DISTRIBUTION

The example will continue with Army forces (AFOR), one of CINC2's components. AFOR sets up 5 nets with its allocated points, and allocates points to 3 of its subordinate units. AFOR keeps 50 of Yellow and Red points in reserve. AFOR can assign lower-priority nets to lower-priority users by employing the priority multipliers, as described earlier. The units that were allocated points from AFOR will also have a UHF SATCOM account to set up nets and allocate points to their subordinate units. After allocation, AFOR's UHF SATCOM account is presented in this slide.

UHF SATCOM STANDARDS: ACCESS AND ALLOCATION OF UHF SATCOM RESOURCES AFOR's POINT ALLOCATION AND DISTRIBUTION

- AFOR SETS UP 5 NETS AND ALLOCATES POINTS TO 3 OF ITS UNITS
- AFOR KEEPS 50 EACH OF YELLOW AND RED POINTS IN RESERVE. BELOW IS AFOR's "UHF SATCOM ACCOUNT":

ITEM	NET NAME	GREEN	YELLOW	RED
INITIAL DEPOSIT	--	200	500	300
ONE 5-kHz DASA	NET 1	-200	--	--
ONE 2.4-kbps ckt	NET 2	--	--	--
ONE 2.4-kbps ckt	NET 3	--	-90	--
ONE 2.4-kbps ckt	NET 4	--	-90	--
ONE 2.4-kbps ckt	NET 5	--	-90	--
UNIT 1	--	--	--	--
UNIT 2	--	--	--	-150
UNIT 3	--	--	--	-100
BALANCE	0	0	0	0

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32. NETWORK AND INDIVIDUAL PRIORITIES

A description of user access would not be complete without discussing the network access class of service (COS) that must accompany the assignment of nets. The controller must have in its database the call priorities allowed for each user on the network for varying conditions. Two kinds of network access COSs must be defined:

- <u>Net COS</u> - Defines the highest precedence that may be used by any individual in a defined net to establish a call to the net.

- <u>Individual COS</u> - Defines the highest precedence with which an individual can place a call to an individual user or undefined net.

Using some of the nets assigned in the example above, these COSs can be illustrated. The JCS NCA net defined in the example is assigned a net COS of priority 1, meaning that when a user who is defined as a member of that net initiates a call to that net, the precedence used to set up the net call is FLASH OVERRIDE (FO), regardless of what his individual COS may be. When this net was defined in the network, it cost the proponent, who was JCS, 500 Blue points.

In contrast, suppose CINC2 set up his C2 net as an individual COS of priority 1, meaning that he can dial up any of his subordinates and talk to them individually, rather than have them all on the same net. This supposes that he has defined his component net to allow him to talk to all component commanders at once. This component net has a net COS of priority 1. CINC2's configuration means that individual subordinate commanders cannot call CINC2 privately with a precedence of FO unless they set up an individual COS of priority 1. They could call him on the CINC2 component net, but they would activate the entire net, and it would not be a private call.

Of course, as was illustrated above, expended priority 1 points can be multiplied for lower priorities, and these lower-priority points may be used to assign individual COSs to various users who talk to many different individuals, rather than the same net all of the time. They may also be used to buy services that could not be bought at a higher priority. The point allocation system provides a great deal of flexibility in assigning services and satisfying a wide range of user situations and requirements.

UHF SATCOM STANDARDS: ACCESS AND ALLOCATION OF UHF SATCOM RESOURCES NETWORK AND INDIVIDUAL PRIORITIES

- **INDIVIDUALS ARE ASSIGNED PRIORITIES BASED ON HOW POINTS ARE SPENT**
- **TWO TYPES OF PRIORITY ASSIGNMENTS EXIST**
  - NET: PRIORITY OF NET IS ASSIGNED TO ALL MEMBERS OF THAT NET FOR ACTIVATION
  - INDIVIDUAL: PRIORITY DEFINED FOR AN INDIVIDUAL TO PLACE CALLS TO ANYONE AT A SPECIFIC PRECEDENCE
- **METHOD OF SPENDING POINTS**
  - IF AN INDIVIDUAL WANTS TO CALL ANYONE AT PRIORITY 1 ON A 25-kHz DASA CHANNEL, 500 GREEN OR BLUE POINTS MUST BE SPENT.
  - IF A PRIORITY 1 NET OF 5 MEMBERS IS SET UP FOR 25-kHz DASA, 500 GREEN OR BLUE POINTS ARE SPENT. ANYONE ON THIS NET CAN ACTIVATE IT AT PRIORITY 1.
  - THE MEMBERS OF A PRIORITY 1 NET CAN HAVE LOWER INDIVIDUAL PRIORITIES, BUT WHEN THEY TALK ON THAT NET, THEY GET PRIORITY 1.

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DEFENSE INFORMATION SYSTEMS AGENCY
JOINT INTEROPERABILITY AND ENGINEERING
ORGANIZATION (JIEO)
FORT MONMOUTH, NEW JERSEY 07703-5613

TUTORIAL ON

SET-UP AND COMMUNICATIONS DELAYS

FOR ALL

UHF SATCOM DAMA MODES OF OPERATION

JIEO REPORT
20 JUNE 1994

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CHAPTER 1

INTRODUCTION

1-1 PURPOSE

The purpose of this tutorial is to address two specific requirements identified at the military satellite communications (MILSATCOM) Users Conference 93-1. These requirements are stated in a Joint Staff Tasking Memorandum [Ref. G], Subject: Tasking Based on MILSATCOM Users Conference 93-1, dated 10 September 1993. Requirements (a) and (b) of that memorandum request that the following actions be taken:

- Identify voice services supported by the ultra high frequency (UHF) demand-assigned multiple access (DAMA) standards (MIL-STD-188-181 through -183). Describe access and utilization procedures, and how they will affect user resource allocation.

- Develop a tutorial describing the call set-up and communications delays for all UHF DAMA modes of operation

This tutorial presents the concept of UHF DAMA from both technical and layman's perspectives, provides information on the constraints of the two DAMA waveforms, and estimates the call set-up times and the magnitude of any communications delays for voice services. The major modes of voice service supported by the DAMA standards are identified, as well as a proposed method for allocating UHF SATCOM resources to user organizations.

The intent of presenting this information is to help users understand exactly what capabilities are available with DAMA. Users appear to be developing a fear that DAMA will lessen or limit their communications capability. This fear stems from

hearing only the few drawbacks of DAMA without hearing the many benefits it offers. This tutorial will explain all the operating modes that DAMA offers and will illustrate how users' needs can be satisfied, as opposed to continuing with the current practice of providing only a limited number of users with dedicated service.

The DAMA system was developed by systems and design engineers based on their understanding of users' needs. A great deal of capabilities and flexibility have been designed into the system, enabling it to meet the entire gamut of user requirements. However, it is a universal truth that to get something better, something must be given in return. Therefore, a great increase in user capability and flexibility must be traded for some inconveniences some of the time. The problem the DAMA program is facing is that users are concentrating on the small inconveniences (the down side), and have not been fully informed of the full range of capabilities and flexibility that will be afforded by the DAMA systems (the up side). The main purpose of this tutorial is to present the whole story, so that users will understand both sides of DAMA and will understand that by giving a little, they can get a great deal in return. They will also see that DAMA does not preclude any capability that they have today, but, rather, it gives users many choices and options to satisfy their UHF satellite communications (SATCOM) needs.

1-2 BACKGROUND

The relatively low operating frequency, low cost, ease of use, and operational flexibility of UHF SATCOM make it the only communications system (commercial or military) that can support certain long-haul tactical, contingency, and covert military operations. However, the UHF SATCOM constellation cannot simultaneously satisfy all user demands for service reflected in the MILSATCOM User Requirements Database. The current terminal

design restricts efficient use of the UHF SATCOM system. Current access techniques are based on single net per transponder (SNPT) and dedicated allocation. Studies indicate that this method results in a limited number of user nets that can be supported by the satellite resources, and it introduces significant inefficiencies in channel use [Ref. E]. For example, when a particular net assigned to a channel is not communicating, channel capacity is wasted.

To overcome the severe shortage of UHF SATCOM channels and this inefficient use, the new terminals will use DAMA techniques in conjunction with time-division multiple access (TDMA) and narrowband voice (2.4 kbps LPC-10). Two waveforms have been defined, one for 5 kHz [Ref.B] and one for 25 kHz [Ref.C], to provide user access on demand. Multiple users share a satellite channel, and subscriber terminals send burst transmissions during a fraction of time known as a TDMA time slot.

Realizing the benefits of DAMA, the Joint Chiefs of Staff (JCS) has issued memorandum MJCS-36-89, requiring all Services to transition to DAMA by the end of FY 96. As this transition point approaches, organizations are asking for more information on the new DAMA system and how its implementation is likely to affect them. Several organizations have studied the implementation standards and have become alarmed at projected call set-up times and communications delays that can occur when operating in the various DAMA modes. These concerns were voiced at the MILSATCOM Users Conference 93-1 and in several official messages to the JCS, which resulted in the issuance of a Joint Staff Tasking Memorandum, dated 10 September 1993. This tutorial addresses several of the actions directed in that memorandum relating to set-up times, communications delays, and user resource allocation.

1-3 APPLICABILITY

This tutorial applies to UHF SATCOM terminals operating over 5-kHz and 25-kHz satellite transponders, in accordance with UHF SATCOM standards [Refs. A, B, and C].

1-4 POLICY

This tutorial was prepared by JIEO, based on Joint Staff direction. It will be used to help UHF SATCOM users understand the operational and communications set-up delays inherent in the current UHF SATCOM DAMA standards for 5- and 25-kHz satellite channels.

1-5 CHANGES

Written recommendations or suggested changes to this tutorial should be submitted to the

Joint Interoperability and
Engineering Organization
ATTN: TBBA (Andreas Pappas)
Fort Monmouth, New Jersey 07703-5513

1-6 REPORT ORGANIZATION

This tutorial is composed of four chapters that address the following subject areas:

- Chapter 1 - Introduction. Provides purpose, background, references, applicability, policy, change procedures, and report organization.

- Chapter 2 - UHF DAMA SATCOM Concepts, Modes, and Voice Services. Provides a discussion of UHF SATCOM DAMA

concepts and modes by using common non-technically oriented examples, and defines the various voice services supported by the DAMA standards.

- Chapter 3 - UHF DAMA Set-up and Communications Delays. Presents the user with set-up and communications delays for the defined voice services, and provides estimates of the expected delays for terminal set-up, call set-up, and waveform delays.

- Chapter 4 - Access and Allocation of SATCOM Resources. Describes the access and utilization procedures and their effects on user resource allocation.

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CHAPTER 2

UHF DAMA SATCOM CONCEPTS, MODES, AND VOICE SERVICES

The purpose of this chapter is to provide a discussion of UHF SATCOM concepts and modes supported by the DAMA standards, using common everyday examples to which a non-technically oriented user can relate. The various voice services provided by the DAMA standards are also defined.

To most users, the term *DAMA* conjures up a host of negative traits concerning an unfamiliar method of changing how they will access UHF SATCOM services. When anything is unfamiliar and new, there is always a fear that something will be lost or sacrificed in the name of progress. This fear is really spawned from not knowing all of the details about a change for the better, and that is exactly the objective of this chapter.

Although the DAMA standards define new radio waveforms for operation on the UHF SATCOM channels that employ a technology called *TDMA*, most users do not realize that not all of the UHF SATCOM channels are required to operate with this waveform. The DAMA standards include provisions for operating in three different modes, as follows:

- Dedicated Channel Single Access - The current practice of assigning a user net exclusive rights to communicate on the dedicated channel.

- Demand-Assigned Single Access (DASA) - Operation on a single channel, requested on demand (using either a 5- or 25-kHz channel only when it is needed) via the DAMA waveforms' control system (controller).

- TDMA/DAMA - Sharing 5- or 25-kHz channel resources on demand, using the new waveforms described in the standards.

DAMA gives the user community what it has today: the dedicated-channel single access, plus two other modes of operation that can substantially increase the number of users that can be served by the same SATCOM resources. Therefore, DAMA has given more options for providing service, not taken away capability. The following sections describe the theory of operation in both technical and layman's terms of how UHF SATCOM is envisioned to operate under the DAMA standards. This chapter presents the following topics:

- UHF SATCOM TDMA - Explains the concept of the new TDMA radio waveforms defined in the DAMA standards, and how many users are able to talk on the same channel simultaneously.

- DAMA Concept - Explains the concept of users sharing a pool of communications resources on demand, to allow a greater number of users to have access to SATCOM services.

- TDMA/DAMA Concept - Explains how the new TDMA waveforms implement DAMA for UHF SATCOM access.

- DAMA Modes of Operation - Explains how DAMA supports three different modes of operation simultaneously.

- Voice Services Supported by the DAMA Standards - Lists and explains the various voice services supported by the DAMA standards.

2-1 UHF SATCOM TIME-DIVISION MULTIPLE ACCESS

This section is divided into two parts to satisfy two different audiences. The first part explains the TDMA concept for those who have a more technical background and like to know a few details about the system. The second part is for the user who would like to understand the concept, but not get involved with the engineering details. Both audiences should read both sections, because a better understanding will be obtained from seeing both a technical and a practical explanation.

A. Technical View of TDMA. TDMA, a communications concept, permits many user nets to share a satellite channel. It is analogous to time-division multiplexing, in which one communications path is divided into time frames, which are further divided into time slots where data from each individual input is placed. With UHF satellite TDMA, each input can be considered a user who has been assigned a time slot. Using this multiple-access technique, a number of user terminals take turns transmitting bursts of data through a common transponder during their respective time slots. Thus, each earth terminal transmission has sole use of the transponder bandwidth and power during the duration of its time slot.

Figure 2-1 illustrates two frames of a TDMA system. Two types of time slots are depicted. The first is the control time slot, in which orderwires carry signaling, control, and management information to control the system. The second is the communications time slot, in which users burst their information to communicate with other users.

Since a continuous stream of information (bits) does not flow over the network, but rather bursts of information during a time slot, to communicate over a TDMA system, a means to store information between bursts is required. This storage procedure is called *buffering*, and it works as illustrated in

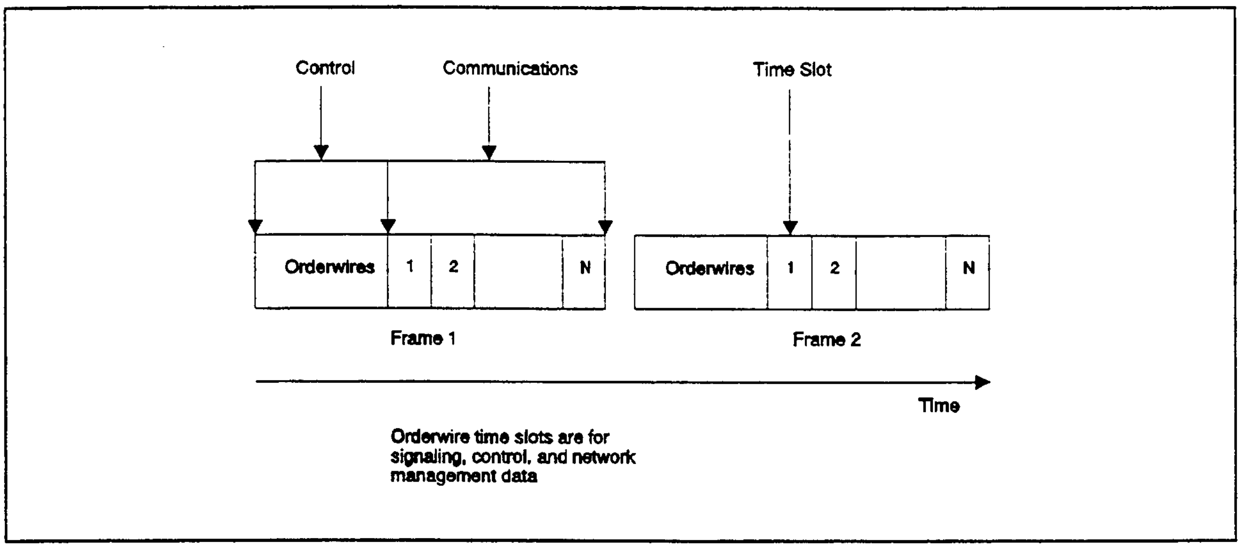


Figure 2-1. General TDMA Frame Format

Figure 2-2. As a user is speaking into his handset, his voice is being converted into a bit stream at 2.4 kbps. If he is talking over a TDMA system with 4 time slots of 1-second duration, he gets to send his information for 1 second out of 4. Note that in the figure one of the time slots in the frame is being used for orderwires. Before a user can send, he must store the voice information, so that when his turn comes to transmit, he can send 4 seconds' worth of information in his 1-second interval. So he needs a storage device (buffer) that can store 4 seconds' worth of speech, which would be 4 times 2.4 kilobits (kb) or at least 9.6 kb. When his time comes up to send information, he must transmit everything in his buffer, which amounts to 9.6 kb. Therefore, for him to burst all of his information, he has to send at a transmission rate of 9.6 kilobits per second (kbps) during his time slot.

The effect of this buffering procedure causes what is known as *waveform delay*. The delay is equal to the length of the TDMA frame in our UHF SATCOM TDMA system. Therefore, the delay that would be experienced would be 4 seconds in our example. As the figure illustrates, the reason for the delay is that as a person is talking, his voice is being stored to be transmitted at a later time in its respective time slot. The time it is stored

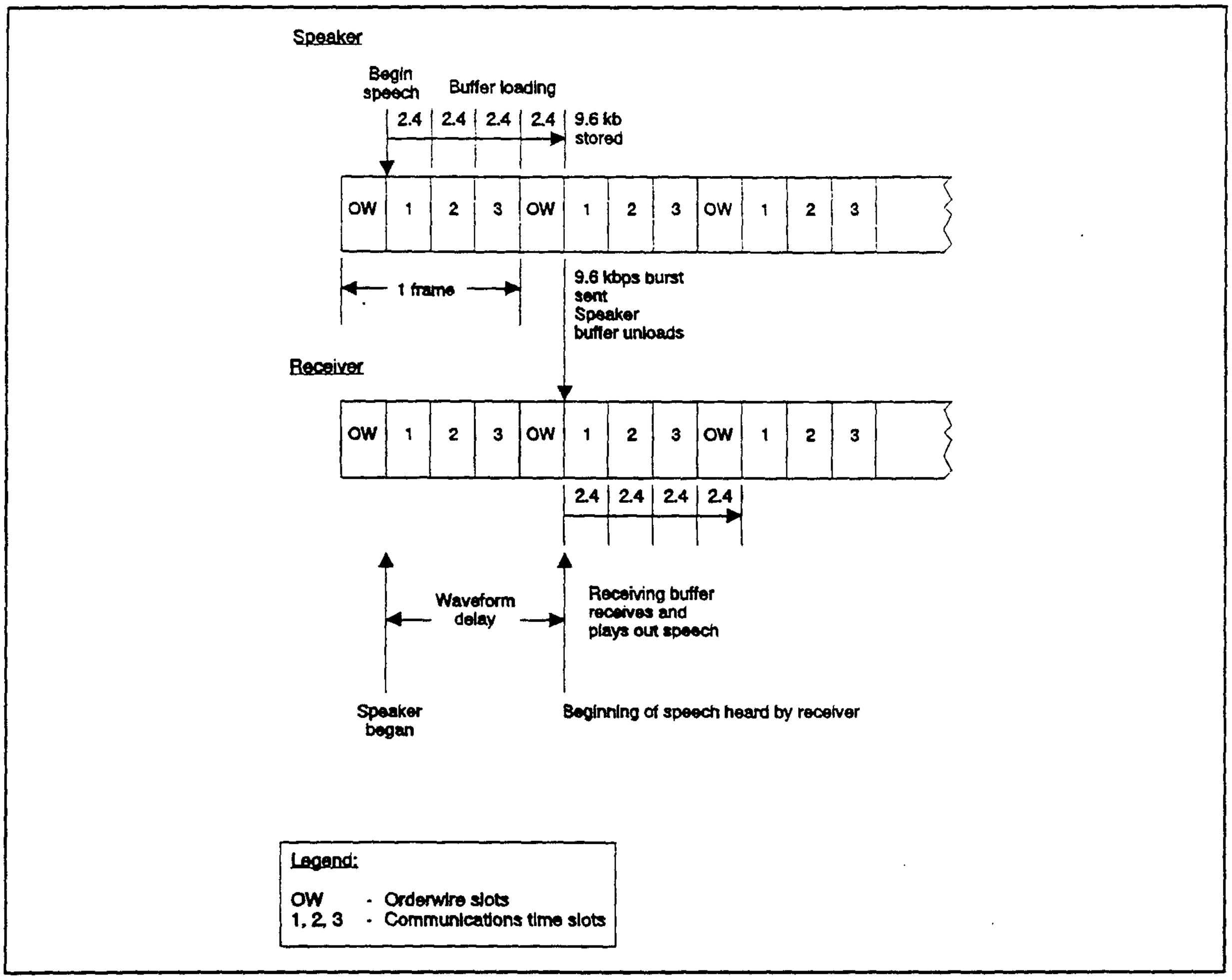


Figure 2-2. Waveform Delay

before transmission is the length of the frame, at which time it is sent and received at the other terminal and played out through another buffer that received the burst of information sent during the time slot. Therefore, the receiver hears the voice of the speaker delayed by the length of 1 TDMA frame, which in our example is 4 seconds.

Two UHF TDMA waveforms have been approved by JCS. The first is for 5-kHz channels and is described in MIL-STD-188-182. The second is for 25-kHz channels and is described in MIL-STD-188-183.

B. Layman's View of TDMA. Non-technical people may find the last few paragraphs confusing. You read terms such as

multiplexing, *frame*, *orderwire time slot*, and *communications time slot*, and you may have gotten lost after the first term. Let us deal first with multiplexing. Multiplexing is a method to get more from the same resources, or multiply a capability. A good example is parking places on a street. Figure 2-3 illustrates two ways of using lineal curb space on a street for

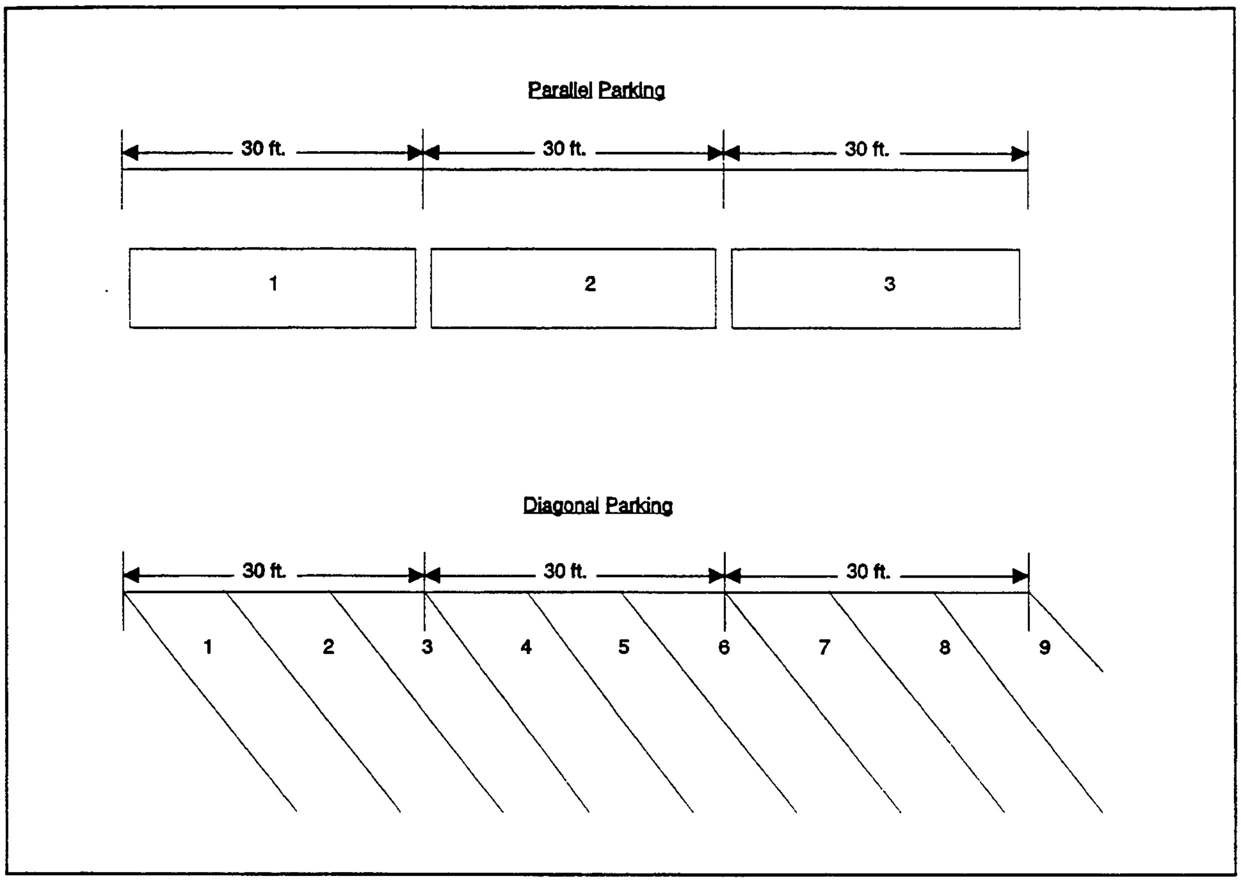


Figure 2-3. Parking Space Example

providing parking spaces. Parallel parking uses more lineal curb space per parking space than diagonal parking. Therefore, the diagonal parking method could be termed a "multiplexing" approach to conventional parallel parking. Notice, however, that we did not get something for nothing. To park more cars, we had to give up some of the width of the street. We had to make a tradeoff to park more cars; but if parking space is more scarce than street width, we live with a narrower street.

The figure illustrates that three cars can be parked in the same spot as one parallel-parked car. We could call this space a *satellite channel* and have either one user in the space or three users in the space. If we decide to multiplex and use diagonal parking, each of the three spaces could be a frame, with three time slots or user spaces. Now we really have to stretch to discuss the orderwire time slot. Suppose, instead of free parking, that every eighth frame we set up a parking attendant house in a diagonal parking space to control who parked where. The parking attendant and his house would take up a time slot but would control access to the parking spaces. The communications time slots are, of course, the parking spaces themselves.

With UHF SATCOM TDMA waveforms, the amount of multiplexing that takes place compared to the parking example is much greater. Up to 20 users can use the same satellite channel at the same time, depending on the type of service they are using (voice or data). We will continue to use the parking example as we examine the DAMA concept.

2-2 DEMAND-ASSIGNED MULTIPLE ACCESS

As with the previous section, DAMA is explained from both a technical point of view and in layman's terms.

A. Technical View of DAMA. DAMA, a communications channel access and resource allocation technique, provides the dynamic sharing of one or more channels among many users or user networks. Thousands of satellite terminals, within the same satellite coverage area, may share the channels of one or more satellites. Worldwide multi-user SATCOM connectivity can be provided by using relay schemes between channels on adjacent satellites of the DOD UHF SATCOM constellation.

The concept of DAMA is very simple. Given a pool of resources that can be shared, such as UHF satellite channels, the

channels can be assigned for use on demand--thus, the term *demand assigned*. Since many users are able to share or access the channels, the system is said to have *multiple access*. Therefore, the term *DAMA* means that multiple users can have access to a pool of resources on demand, which translates in our case to UHF SATCOM assigned to users on demand. Channel capacity is not wasted when the particular net assigned to a channel is not communicating.

Besides improving the efficiency of space resources, DAMA provides efficient use of the terminal segment. DAMA satellite terminals can participate in multiple networks, because they can be designed with the ability to communicate on any of the UHF MILSATCOM channels, both 5- and 25-kHz.

B. Layman's View of DAMA. Going back to our parking example, and considering that a parking space is equivalent to a UHF SATCOM channel that can be assigned to a communications net, we can make some clear comparisons. In a pure demand-assigned situation, when a person needs a parking space, he takes any one that is available and uses it until he is finished, whereupon, when he leaves, another person can park there. If we wanted to authorize users to use spaces, we could require that a parking permit or sticker be required, and have the parking attendant check permits. Rather than giving a person a reserved parking space, as when we give someone a dedicated channel for communications, we would allow many people to share the spaces on demand. In the case of a reserved spot when it is not being used, it is wasted. If you have no reserved parking spot, and you are looking for a place to park, you get upset when you see empty reserved spaces and you cannot use any of them. UHF DAMA can prevent this situation. Consider, if every parking spot were reserved for a specific person in town, the number of people who could park would be the finite number of parking places that existed. If spaces were provided first-come, first-served (or

demand-assigned), the number of people who could park would be many times the finite number of parking spaces available.

2-3 UHF SATCOM TDMA/DAMA

This section discusses the effects of combining the TDMA multiplexing technique with demand assignment as it pertains to UHF SATCOM. The concept described is for operation in the pure DAMA mode, using the new DAMA waveforms and assigning communications resources on demand. This concept is explained in both technical and layman's terms.

A. Technical View of TDMA/DAMA. The concept of TDMA/DAMA is also very simple. TDMA, or dividing the communications channel into time slots, is used in conjunction with assigning the time slots to users on demand, to allow them to communicate over the system. This method, as it is applied to UHF satellite systems, is illustrated in Figure 2-4. The figure illustrates three phases associated with user communications using TDMA/DAMA on the UHF satellite network:

- Link set-up - User A requests a communications path to User B by sending an orderwire message to the controller. The controller assigns an idle time-slot to the call and sends both User A and User B an orderwire message to use that time-slot for communications

- Communications - User A communicates with User B on the assigned time slot for as long as they need the communications path.

- Link release - When the communications between User A and B is completed, an orderwire message is sent to the controller indicating that the connection is no longer needed. The controller

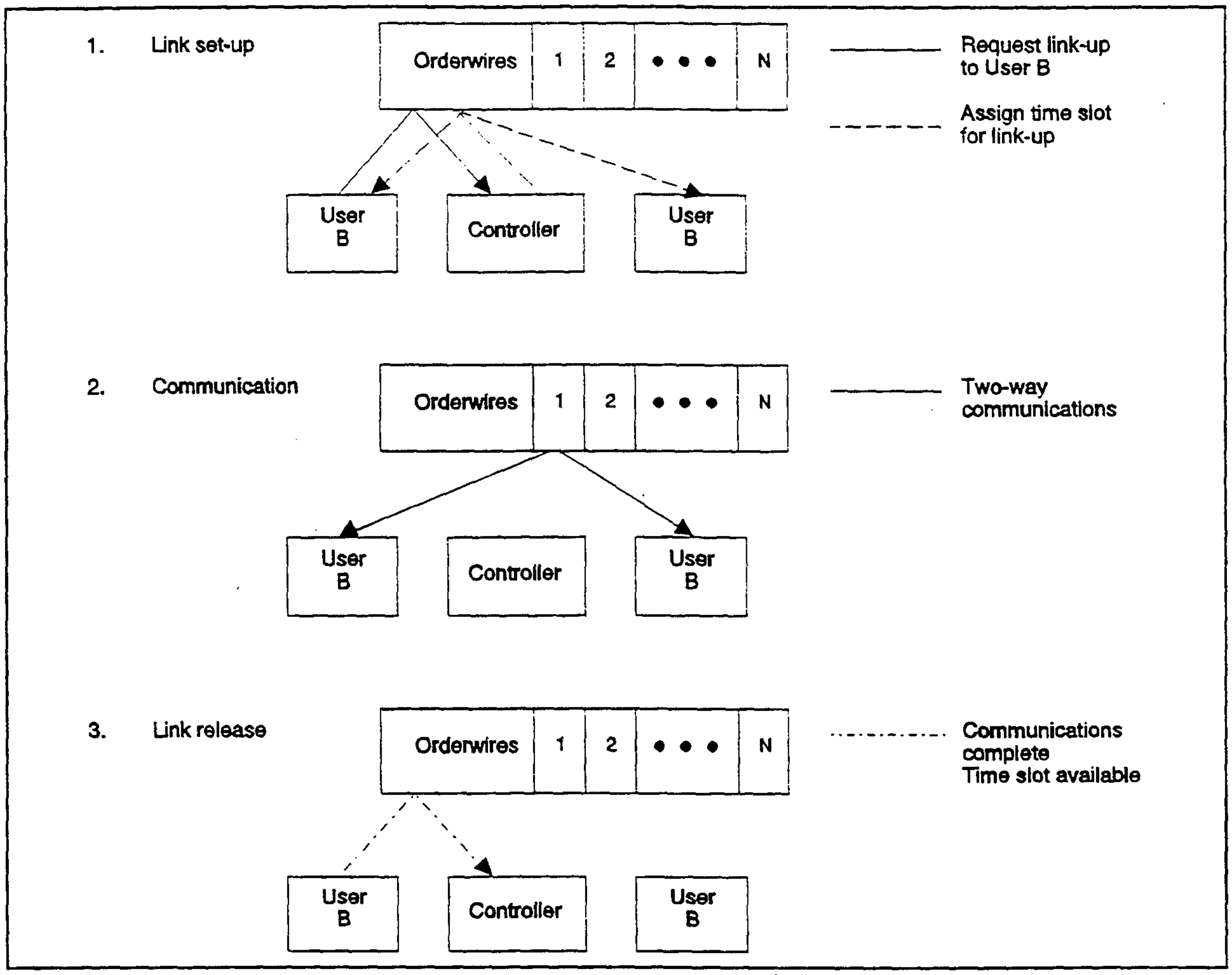


Figure 2-4. UHF SATCOM TDMA/DAMA Concept

then makes the time slot available to accommodate other service requests.

Since there is a pool of channels, which can be divided into many communications paths (time slots), many users can be communicating simultaneously. And since <u>all</u> do not need to communicate at the <u>same time</u>, many more can be served than if each net of users is assigned a dedicated communications path.

B. Layman's View of TDMA/DAMA. Continuing to use our parking example, with a parking space representing a UHF SATCOM communications channel for a user net, we can make more comparisons. We now will combine our multiplexing technique with demand assignment. Instead of using the parallel parking method,

we will park diagonally (multiplex) and have three times as many parking spaces as before. As before, in a pure demand-assigned situation, a person needing a parking space takes any one that is available and uses it until he is finished. When he leaves, another person can park there. We can control access by authorizing users to use spaces through parking permits or stickers, or making people see the parking attendant before they take a space. The parking attendant becomes the controller of the available spaces.

2-4 UHF SATCOM DAMA MODES

The area most misunderstood about UHF DAMA involves the various modes in which it can operate. This section explains the vast flexibility and capability of the UHF DAMA system to meet all user situations. The important message in this section is that UHF DAMA has not taken away any of the capabilities that exist today, but rather has significantly enhanced availability of UHF SATCOM to users. The system can provide all of the following modes simultaneously:

A. Technical View of the DAMA Modes. This section presents the technical view of the three DAMA modes supported by the DAMA standards.

1. Dedicated Access. This mode is the way the system is operated today. A user net is assigned a UHF SATCOM channel for communications and no other users can use it. Either a 5-kHz or a 25-kHz channel can be assigned for dedicated use. The terminals communicating on the dedicated channel do not operate using the DAMA waveform, but rather in the conventional mode. Using operating procedures yet to be developed for system management and control, a terminal operating in the DAMA waveform could request a dedicated channel via the orderwire, get an assignment, then switch to that channel and operate in the conventional mode.

2. Demand-Assigned Single Access. This mode was added in the last revision of the DAMA standards to address the problems of waveform delays within the demand-assigned mode. This mode is implemented with a terminal operating in the DAMA waveforms. A request for a single channel is placed on the orderwire, the controller assigns an idle channel (either 5- or 25-kHz, depending on bandwidth requirements, availability, or both), the communicating terminals receive the assignment over the control orderwire, switch to the assigned channel, and operate in the conventional mode on the assigned channel. When they are finished communicating, they switch back to the DAMA waveform, send a Call Complete message on the orderwire, and continue operating in the DAMA mode as usual. Essentially, this mode provides a dedicated channel for use by a net when they need it. When they are not communicating, this channel is released for use by others who need it. If one considers that the average net uses a channel for 6 minutes an hour, and all nets usually do not talk at the same time, sharing channels significantly increases the number of nets that can get dedicated service when they need it. One drawback of this mode is that while a net is communicating on a DASA channel, orderwires are not received. Therefore, preemption of the circuit cannot be accomplished. This situation can be mitigated by limiting lower-priority users to a fixed amount of time to use the DASA channel, while always allowing priority 1 users unlimited use when they need it.

3. TDMA/DAMA. This mode allows all users access to UHF SATCOM service based on their assigned priority. The terminals operate in the DAMA waveform and request service when they need it. The channels operating the DAMA waveforms are divided into time slots that can provide various data rates to accommodate both voice and data communications. Communicating terminals are assigned time slots to use based on their assigned priority. Priorities are assigned similar to the precedence levels used in the Defense Switched Network (DSN). Users with lower priorities can be preempted when a higher-priority user

must communicate and there are no idle time slots to provide the service.

The concern of many users about DAMA is that they want "assured access" to the system. The answer to this requirement is to give all users requiring assured access the highest priority, and limit that number of users to the number of total available communications paths that can be set up at any one time. This means that in the unlikely event all of these high-priority users wanted to talk at exactly the same time, there would be enough communications paths to accommodate them. The beauty of this system is that there is a priority level for everyone. The priority level can be dynamically upgraded or downgraded, depending on assigned missions using the system management and control network.

A low-priority user, who under the old system of dedicated channel assignments would never have access to communicate over the UHF SATCOM network, can request access to the network anytime he wishes. If there are idle time slots, he can get service. If he is denied service or gets preempted, he will learn to use the system at off-peak times, but he will still be able to communicate, where before he did not even have an opportunity. The users who have the dedicated channels now will get the highest priority and will have access whenever they need it. The users with priorities in between will get better service than they get right now with significantly less red tape and coordination. Remember, however, that to have this great improvement in capability and flexibility, something has to be given in return. This is not to say that those who cannot afford to give something up will be forced to. The system is flexible enough to meet all special situations, if a user is willing to pay the price for them. The price is discussed under the resource allocation chapter of this tutorial, Chapter 4.

B. **Layman's View of the DAMA Modes.** To explain the DAMA modes, let us introduce another example and compare the TDMA/DAMA concept to a large hotel. This hotel has 500 rooms on 20 floors with 25 rooms per floor. The hotel itself represents a satellite with 20 transponders (channels). Each floor of the hotel represents one of the satellite's transponders or channels. Since the channels can be divided into time slots for communications, the rooms on a floor represent communications time slots. The hotel registration desk represents the system controller. For the sake of time comparison, let us say that a day's stay at the hotel is equal to 1 minute of a UHF SATCOM communications duration. Having made these comparisons and representations, let us draw comparisons to using the space available in this hotel to the resources of a UHF SATCOM satellite.

1. <u>Dedicated-Channel Single Access</u>. We could represent this situation by saying that whenever the President comes to this city, he stays at this hotel. The hotel sets aside an entire floor for him. For security purposes, this floor is never used for any other purpose other than for the President's visits. It remains secure and not used, even when he is not visiting this city.

2. <u>Demand-Assigned Single Access</u>. We can represent this situation by considering that various VIPs visit this city from time to time. When they are in town, they reserve an entire floor at the hotel for the number of days that they need it. To make these arrangements, reservations are made with the hotel registrar, who checks to make sure there is available space during the requested stay. In this case, the hotel floor can accommodate more than one VIP party in a year. If each VIP wanted to stay a week, ideally, 52 different VIPs could use that floor during the year. That is certainly better use of an entire floor than that from the President's dedicated floor.

3. TDMA/DAMA. We can represent this mode by considering that when people are visiting this city on travel, they call ahead to the hotel registrar to reserve a room for their stay. The reservation system assures that they have sufficient space at the appropriate time for all people who have requested rooms. The rooms are used by a number of different people only when they need them. Under this plan, 25 different individuals can have rooms every night on each floor. Thousands of different people can be accommodated by one floor in an entire year. Tens of thousands of people can be accommodated by all the floors of the hotel in this mode of operation; however, let us remember that we can still set aside the one floor for the President, we could set aside a couple of floors for visiting VIPs, and use the rest for the people who just need a room for a couple of nights. We can do it all simultaneously, and it is the same with the DAMA system. It is all a matter of configuring the resources to meet the requirements of the customers/users. We do this allocation of resources through the management and control system, which will be in charge of programming the system controllers that control access to the UHF SATCOM network.

2-5 DEFINITION OF VOICE SERVICES SUPPORTED BY DAMA STANDARDS

This section defines the various voice services supported by the DAMA standards. The services are divided into three segments governed by the type of control orderwire from which services are assigned. For example, if a terminal is operating in the 25-kHz DAMA waveform, it is receiving and sending orderwires on its assigned "home channel." Some terminals will operate with 25-kHz home channels, while others will operate with 5-kHz DAMA on 5-kHz home channels. System control can direct any terminal to change its home channel, frequency band of operation, or both. The purpose of identifying the various voice services available is to demonstrate the set-up and communications delays that can be expected for each of these services.

The orderwires for the 5-kHz and 25-kHz waveforms use different nomenclatures. Orderwires from the controller to the terminals are called forward orderwires (FOW) for 5-kHz and channel control orderwires (CCOW) for 25-kHz waveforms. Similarly, orderwires from the terminals to the controller are called return orderwires (ROW) for 5-kHz and return channel control orderwires (RCCOW) for 25-kHz waveforms.

A. 25-kHz Orderwire. Voice services available through the 25-kHz orderwire are summarized below. The delays for set up of a service are primarily associated with the number of orderwire slots and the time delay between orderwire transmissions. In the case of UHF DAMA, orderwires are sent every frame, so the major limiting factor for call set up is the frame length, which is 1.4 seconds for the 25-kHz DAMA waveform.

1. TDMA/DAMA Services. Service requests for TDMA/DAMA voice may be satisfied by providing either a 2.4-kbps time slot for narrowband voice or providing a 16-kbps time slot for wideband voice. In 25-kHz TDMA/DAMA operation, a time slot can be assigned on a terminal's home channel or on any other DAMA operating channel in that satellite. If the terminal is communicating on other than its home channel, it must switch back to its home channel every frame to monitor the control orderwire during the CCOW interval.

2. DASA Services. Service requests for DASA service may be satisfied from terminals operating in the 25-kHz waveform via their home-channel orderwire. Services offered are either 2.4 kbps on a 5-kHz channel or 16 kbps on a 25-kHz channel. The controller instructs the terminal to leave its home channel and switch to an idle channel to operate, using MIL-STD 188-181. When communications are complete, the terminal returns to its home channel and sends a Call Complete message to signal to the controller that the channel is available for reassignment. Notice that while terminals are communicating on the DASA

channel, they do not receive any orderwires. This drawback results in the loss of preemption capability of the DAMA system. The drawback is controlled by assigning terminals a time limit for use of the channel. The time limit is based on a user's priority.

B. 5-kHz Orderwire. Voice services available through the 5-kHz orderwire are summarized below. As in the 25-kHz mode, the delays for set up of a service are primarily associated with the frequency of the orderwires and the time delay between orderwire transmissions. In the case of the 5-kHz DAMA waveform, orderwires are sent every frame, so the major limiting factor for call set up is the frame length, which is about 9 seconds.

1. TDMA/DAMA Services. Service requests for DAMA voice may be satisfied by providing a 2.4-kbps time slot for narrowband voice. In 5-kHz TDMA/DAMA operation, a time slot must be assigned on a terminal's home channel, because the waveform protocols cannot support communicating on 1 channel while monitoring the orderwire on another channel, as does the 25-kHz waveform.

2. DASA Services. Service requests for DASA service may be satisfied from terminals operating in the 5-kHz waveform via their home-channel orderwire. Services offered are either 2.4 kbps on a 5-kHz channel or 16 kbps on a 25-kHz channel. The controller instructs the terminal to leave its home channel and switch to an idle channel to operate, using MIL-STD 188-181. When communications are complete, the terminal returns to its home channel and sends a Call Complete message to signal to the controller that the channel is available for reassignment.

C. Dedicated. This mode represents the manner in which channels are assigned today. Voice services can occur using either 2.4 kbps on a 5-kHz channel or 16 kbps on a 25-kHz channel. This mode can be implemented on a pre-arranged basis or

from the DAMA mode through assigning an indefinite time limit DASA channel.

CHAPTER 3

UHF DAMA SET-UP AND COMMUNICATIONS DELAYS

The purpose of this chapter is to present to the user the set-up and communications delays for the various voice services supported by the DAMA standards, and to provide estimates of the expected delays for each voice service. The delays are presented with respect to the steps that a user must logically take to establish communications over a UHF SATCOM link in the three different modes of DAMA operation. Below are the three categories of delays:

- Terminal Set-up Delays - The time it takes to set up the terminal to get ready to communicate.
- Link Set-up Delays - The time it takes to establish a communications path with called user or net.
- Waveform Delays - The time delay associated with buffering voice signals that is required to operate in the TDMA waveform.

3-1 TERMINAL SET-UP DELAYS

Terminal set-up delays consist of two elements: terminal installation and waveform acquisition. These delays can be viewed as those experienced between the time it is decided to install a terminal until the terminal is prepared to accept a user request for communications service.

A. Terminal Installation. This delay is the time required to physically prepare the terminal for communicating. For a manpack terminal, this is the time required to remove the terminal from the pack, deploy and orient the antenna, connect all cables, turn the power on and warm up, and initialize the

terminal. Based on information provided by UHF SATCOM users, during DAMA briefings, an average time to perform these actions is 4 to 5 minutes. (Special Operations personnel have stated this can be reduced to 2-3 minutes, but, on the average, 4 to 5 minutes is typical.) The AN/PSC-5 specification calls for terminal installation within 2 minutes. This delay is not unique to the new waveforms being implemented, except for terminal initialization, which requires seconds to complete. Therefore, the terminal initialization delay will not be considered further.

B. Waveform Acquisition. This delay is the time required to synchronize with the TDMA waveform, which is essential to permit terminals to participate in the network. To request service, 5-kHz users must also login with the DAMA controller, and login takes a finite time to complete. To establish a basis for delay analysis, it is assumed that the actions required to attain waveform acquisition are sequentially performed automatically by the terminal equipment, following operator initiation via key commands. Each of the actions described below must be completed in the order discussed. The minimal delay identified in the following paragraphs is a function of transmitter turn-on time and the delays internal to the terminal equipment for forwarding commands to the receiver or transmitter. For example, in the case of the AN/PSC-5, the transmitter and receiver turn-on time is .875 milliseconds. This turn-on time and other internal terminal delays depend on terminal design. These waveform acquisition delays apply only to the TDMA/DAMA and DASA modes.

1. 5-kHz Waveform Acquisition Delays. Acquisition delays include the time required to complete downlink acquisition, uplink acquisition, and login.

a. Downlink Acquisition. The terminal must acquire and interpret the forward orderwire (FOW) transmitted from the DAMA controller. This is the first action required to

synchronize terminal timing with the TDMA frame. The actions required to perform this synchronization and interpretation consist of acquiring downlink symbol, time slot, and frame timing, and decoding the FOW.

The acquisition delay is based on the point in time that the signal acquisition is attempted relative to the position of the TDMA frame. Figure 3-1 depicts this delay. The maximum delay in obtaining the FOW is approximately 9 seconds, assuming the acquisition attempt is made immediately following an

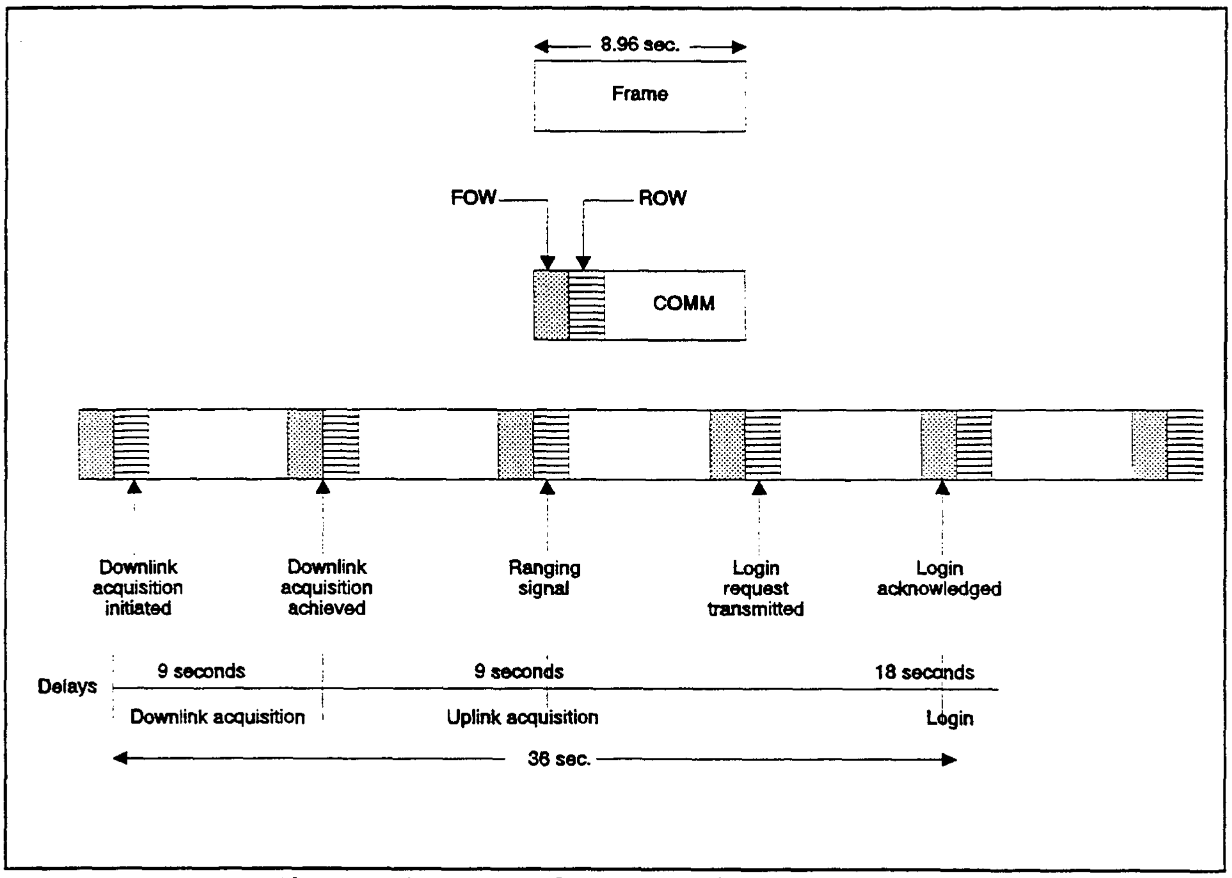


Figure 3-1. 5-kHz Acquisition Delay

occurrence of a FOW transmission. This delay could be much less if the acquisition attempt were initiated just prior to the occurrence of the FOW. If attempted just prior to the FOW, this delay could be in the range of milliseconds (minimal). Following

receipt of the first FOW signal, the synchronization process is completed.

The activity of other terminals in acquiring the downlink synchronization has no effect on a terminal's ability to perform this step. The term used to indicate that possible interference among terminals can occur is called *contention*, meaning that terminals are sharing a resource and the possibility exists that they may try to perform an action at the same time and interfere with one another. Normally contention is concerned with a transmit action, and since downlink acquisition is a receiving process, no contention is experienced with accomplishing this acquisition.

b. Uplink Acquisition. Uplink acquisition is the next step in aligning terminal timing with that of the TDMA frame. This is accomplished by a procedure called *ranging*. For initial entry into a network, two methods of ranging may be used, active ranging and passive ranging. Active ranging is performed by transmitting a short burst to the satellite and calculating the time delay for a signal to travel from the terminal to the satellite. This transmission is done in the return orderwire (ROW) time slot allocated for ranging, called the *contention-ranging time slot*. The 5-kHz waveform provides a variable number of contention-ranging time slots in each frame. The number of contention-ranging time slots available in the next frame is contained in the FOW.

Terminals properly equipped can perform passive ranging to determine timing and do not have to transmit a burst in the ROW. It should be noted that the new Enhanced Manpack UHF Terminal (EMUT) can perform passive ranging. The time required to complete this passive ranging will not be addressed in this tutorial.

The earliest time that uplink acquisition can be accomplished is the ROW time slot in the frame following the receipt of an FOW. This delay is required to determine which time slots are available for ranging in the next frame. Figure 3-1 depicts this delay of approximately 9 seconds, which occurs between receipt of the last FOW and occurrence of the ROW in the next frame. This delay would be minimal if the acquisition were initiated just prior to the occurrence of a FOW.

If a large number of terminals attempt ranging simultaneously, collisions can occur. This means that two or more terminals have transmitted in the same time slot, and all transmitted information is lost. Under these circumstances, each terminal waits and retransmits in a randomly selected future frame and a randomly selected time slot within that frame. Appendix A discusses the random delay algorithm and the associated delays in further attempts to attain uplink acquisition.

c. Terminal Login. Prior to initiating user requests for service, each terminal must login with the DAMA controller. This is accomplished by transmitting a Login message in the ROW and receiving a positive acknowledgment in a Login Response message via the FOW. This login message includes information concerning data-rate capability, link-quality requirements, guard list, and terminal type. This information insertion into the terminal is part of the initialization discussed under terminal installation.

These time delays are experienced by any terminal operating in the DASA or TDMA/DAMA mode of operation. Figure 3-1 depicts the delays experienced in login. The first ROW available for login occurs 9 seconds later than the one used for ranging. Upon receipt of this login request, the DAMA controller transmits a login acknowledgment message, which is transmitted in the first available FOW or approximately 9 seconds

later. This results in an approximate delay of 18 seconds after completion of uplink acquisition to complete login, assuming no collisions have occurred.

As with the ranging transmissions, there is contention for access to the ROW time slots. If a login acknowledgment is not received within 4 frames following transmission of the login request, or a total of 36 seconds, the terminal assumes the request was not received by the DAMA controller. In this situation, the terminal automatically retransmits login requests after random delays. Appendix A discusses the algorithm for retransmission of login requests and how they affect delays.

Note that the login requirement can be bypassed if the terminal login was done previously with the DAMA controller. This is referred to as *preassigned login*. Preassigned login must include all information included in the ROW login message.

2. 25-kHz Waveform Acquisition Delays. Acquisition delays include the time to acquire synchronization for both the downlink and uplink.

a. Downlink Acquisition. This downlink acquisition serves the same function as for the 5-kHz waveform. Due to differences in frame lengths and design, the delays are different than those for the 5-kHz waveform. This acquisition is referred to as *receive timing acquisition* for the 25-kHz waveform and is based on the terminal's achieving frame synchronization lock on the CCOW transmitted from the DAMA controller. Frame lock is achieved when the terminal successfully receives two consecutive CCOW transmissions.

Figure 3-2 depicts the delays for downlink acquisition. The initial delay is based on the time that the

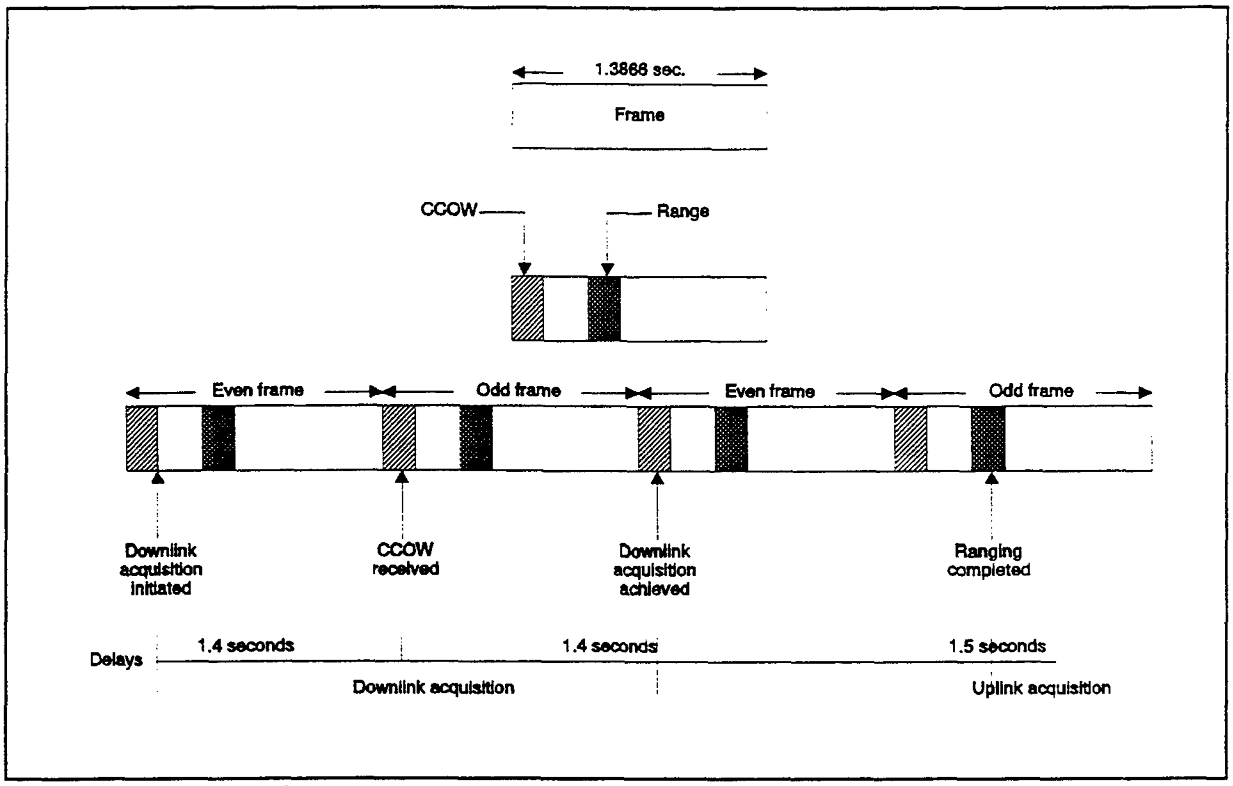


Figure 3-2. 25-kHz Acquisition Delay

acquisition is attempted relative to the position of the TDMA frame. This delay could be approximately 1.4 seconds. The delay would be minimal if the acquisition were attempted just prior to the CCOW. The CCOW is acquired after this initial delay, and with the receipt of the next CCOW 1.4 seconds later, downlink acquisition is complete. There is no contention experienced in downlink acquisition.

b. Uplink Acquisition. This acquisition serves the same purpose as the 5-kHz waveform. This delay is referred to as *transmit timing acquisition* for the 25-kHz waveform. Active ranging is accomplished by transmitting a burst in the range segment of an odd-numbered frame, which is a contention time slot. After achieving CCOW acquisition, the terminal selects the first available odd-numbered frame to perform ranging. Again, ranging can be done passively.

As noted in Figure 3-2, if downlink acquisition were completed in an even frame, the terminal would have to wait slightly more than 1 complete frame to transmit the ranging signal or approximately 1.536 seconds. The .136 seconds is the length of User Segment A of the waveform that lies between the CCOW and Range time slots. Note that if downlink acquisition were completed in an odd frame, the terminal could transmit the ranging signal within the same frame. The delay in this case would be approximately .136 seconds or the length of User Segment A of the waveform.

There is an additional delay that could be experienced in achieving uplink acquisition, which is related to receiving and interpreting the master frame. The master frame occurs every 11.1 seconds (8 frames) and contains frame format and other parameters needed to operate on the channel, including designation of which frames are odd and even. During downlink acquisition the CCOW is received and interpreted. Two consecutive CCOWs are received to accomplish this acquisition. If the initial CCOW interpreted during downlink acquisition is the one immediately following the master frame, there is a delay of 6 frames (8.4 seconds) to receive and interpret the master frame. This delay is not experienced if one of the CCOWs interpreted during downlink acquisition is in a master frame.

If active ranging is unsuccessful due to collisions, the terminal performs additional ranging based on a random process. Appendix A discusses the delays associated with follow-on attempts to complete the ranging procedure.

c. Login. No defined procedure exists in MIL-STD-188-183 for how a terminal logs onto the 25-kHz DAMA network. The RCCOW does not define such a message. Login is accomplished with a service request or link set-up, discussed below in paragraph 3-2.

3. Total Waveform Acquisition Delay. Table 3-1 lists the time delays that would be experienced in preparing a terminal to process user requests for service with no collisions during ranging or login. These times, therefore, represent the best case, or least time, that can be expected to complete terminal set-up. The worst-case delays in completing terminal set-up, as discussed above, are based on the retransmit algorithms associated with uplink acquisition (ranging), and login for the 5-kHz waveform; and uplink acquisition (ranging) for the 25-kHz waveform, which is based on random delays.

Table 3-1. Waveform Acquisition Delays with No Collisions

DELAY TYPE	**DELAYS (SECONDS)**	
	5-kHz Waveform	**25-kHz Waveform**
Downlink Acquisition	minimal to 9	minimal to 2.8
Uplink Acquisition	9	1.5 to 9.9
Login	18	not separately required
TOTAL	27 to 36	1.5 to 12.7

3-2 LINK SET-UP DELAYS

This paragraph examines the delays experienced from the time a user initiates a request for service until the DAMA controller responds to the request by notifying the calling and called party of the resources allocated for the requested service. This delay is similar to dialing a telephone and waiting for an answer.

Link set-up delays fall into two categories, defined as operator/user entry and link signaling protocol delays. The delays between the time the assigned time slots are available for service and the time an individual begins to talk are not

considered, since this delay is variable, based on operator experience.

A. **Operator/User Entry.** The delay in initiating a service request when operating in the TDMA/DAMA and DASA modes is minimal but does take more time to complete than for communicating in the dedicated mode. For the dedicated mode, the handset is picked up, the called party is signaled, and talking begins. The only delay experienced in this case is the time required to initiate the signaling and the propagation time for the signal to travel over the satellite system, which is 238 milliseconds.

TDMA/DAMA and DASA operation require additional operator action to develop the circuit set-up request message. This message includes 10 separate entries by the operator for 5-kHz operations. The additional delay is only a few seconds. These delays apply to both 5- and 25-kHz DAMA operations. The standards have no control over this delay. However, the specifications for the terminals can include requirements for preset calling lists and other preprogramming options to reduce this delay. This delay will not be considered further.

B. **Link Signaling Protocol.** These delays are those associated with waiting for allocation of resources to communicate with another user, following initiation of a request for service. The delays experienced when requesting service using the DAMA orderwire system are determined primarily by the frame design and apply to TDMA/DAMA and DASA modes.

1. <u>5-kHz Waveform</u>. The delays experienced are determined primarily by the long frame length, which is approximately 9 seconds. When a user request is initiated, the terminal prepares a ROW Circuit Setup Request message for transmission to the DAMA controller. Upon receipt of the ROW message, the DAMA controller determines whether the requested

service can be provided. The request is responded to by forwarding a FOW Circuit Assignment message.

Figure 3-3 depicts the link-signaling protocol delays experienced, assuming there are no collisions in accessing the ROW time slots and time slots are available to respond to the

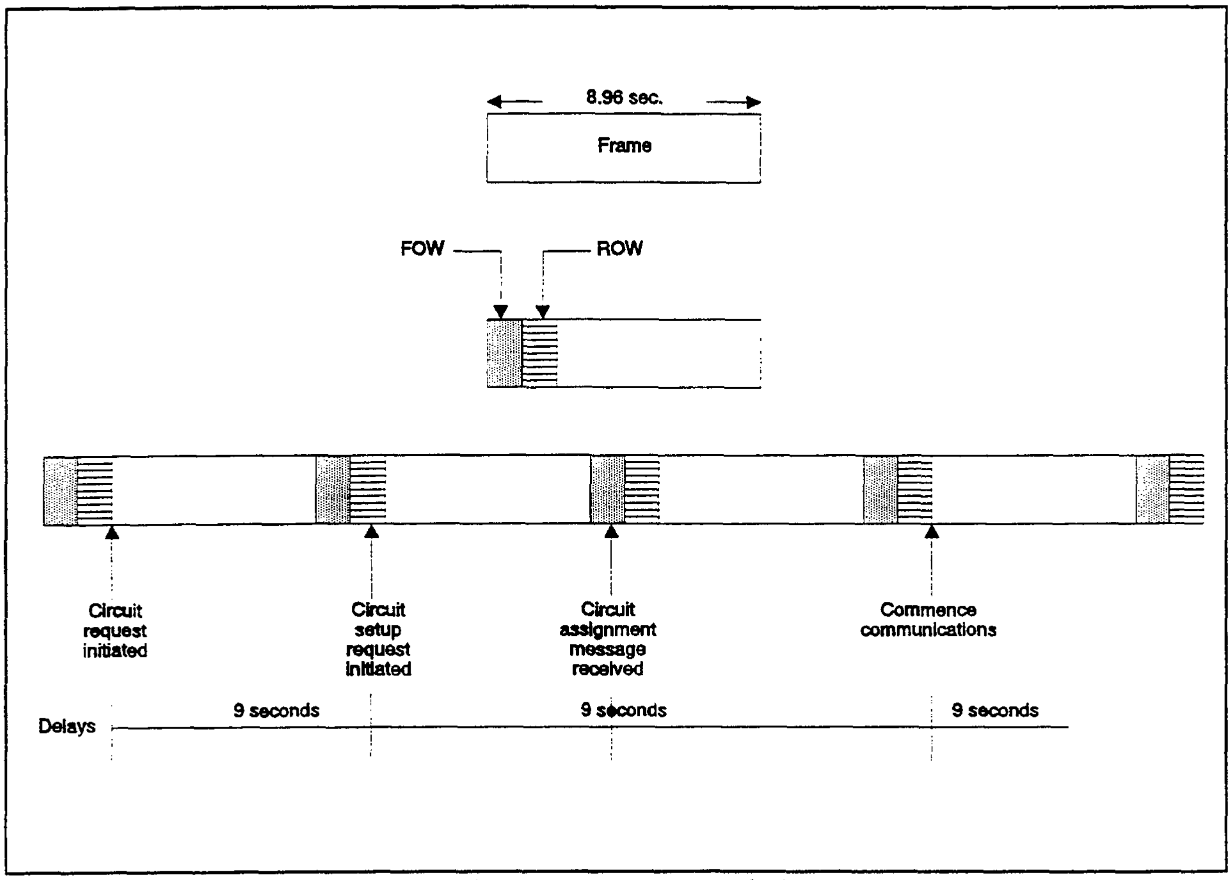


Figure 3-3. 5-kHz Waveform Link Set-up Delay

service request. The service request is noted on the left side of Figure 3-3. Based on the point in the frame cycle that this request is made, there could be a maximum delay of approximately 9 seconds. This delay would be minimal, if the service request were accepted by the terminal just prior to the occurrence of the ROW time slot. The delay results from the terminal's having to delay transmission of a service request until the ROW time slot comes up. The request is received at the DAMA controller and a FOW message is transmitted in the next available FOW, or approximately 9 seconds after ROW transmission. Any time-slot

assignment designated in the FOW for communications would be for the next frame, not the current one, so there is another 9-second delay before the user could begin communications with the called party. Therefore, the user can begin communications within 18 to 27 seconds from the time the service request was initiated.

For the DASA mode, the 5-kHz DAMA orderwire is used to assign a single 5-kHz channel or a 25-kHz channel, using a Terminal Channel Assignment FOW message. The terminal must respond with a ROW, in a time slot assigned by the DAMA controller, to acknowledge the channel change. As done for TDMA/DAMA operation, all time slots are assigned for the next frame following receipt of the FOW circuit assignment. Thus, for DASA operations, the delay for circuit setup would also be 18 to 27 seconds.

In both the TDMA/DAMA and DASA modes, there could be collisions on the ROW, and the service request may not be received at the DAMA controller. Should this happen, there would be a 30-second delay before the terminal assumes the ROW was not received by the DAMA controller. Should this happen, the terminal selects a random future frame to retransmit the service request message. Appendix B discusses the delays associated with further transmissions of service requests under these circumstances.

Should time slots not be available to satisfy the service request, the DAMA controller would forward a FOW acknowledgment message to advise that the service request is queued or why the request was rejected. This message should be received by the terminal within 4 frames, or 36 seconds, after transmission of the service request. If the request were placed in a queue, the delay in responding to the request would be variable, based on the level of traffic, including such things as priority of users requesting service or whether the called party is engaged in another call.

2. <u>25-kHz Waveform.</u> The delays experienced are determined primarily by the frame length, which is 1.4 seconds. When a user request is initiated, the terminal prepares a RCCOW message to request service. Upon receipt of the RCCOW message, the DAMA controller determines whether the request can be satisfied. The request is responded to by forwarding a CCOW message.

Figure 3-4 depicts the link-signaling protocol delays experienced, assuming there are no collisions in accessing the RCCOW. Other delays may occur if (1) the RCCOW slot has been

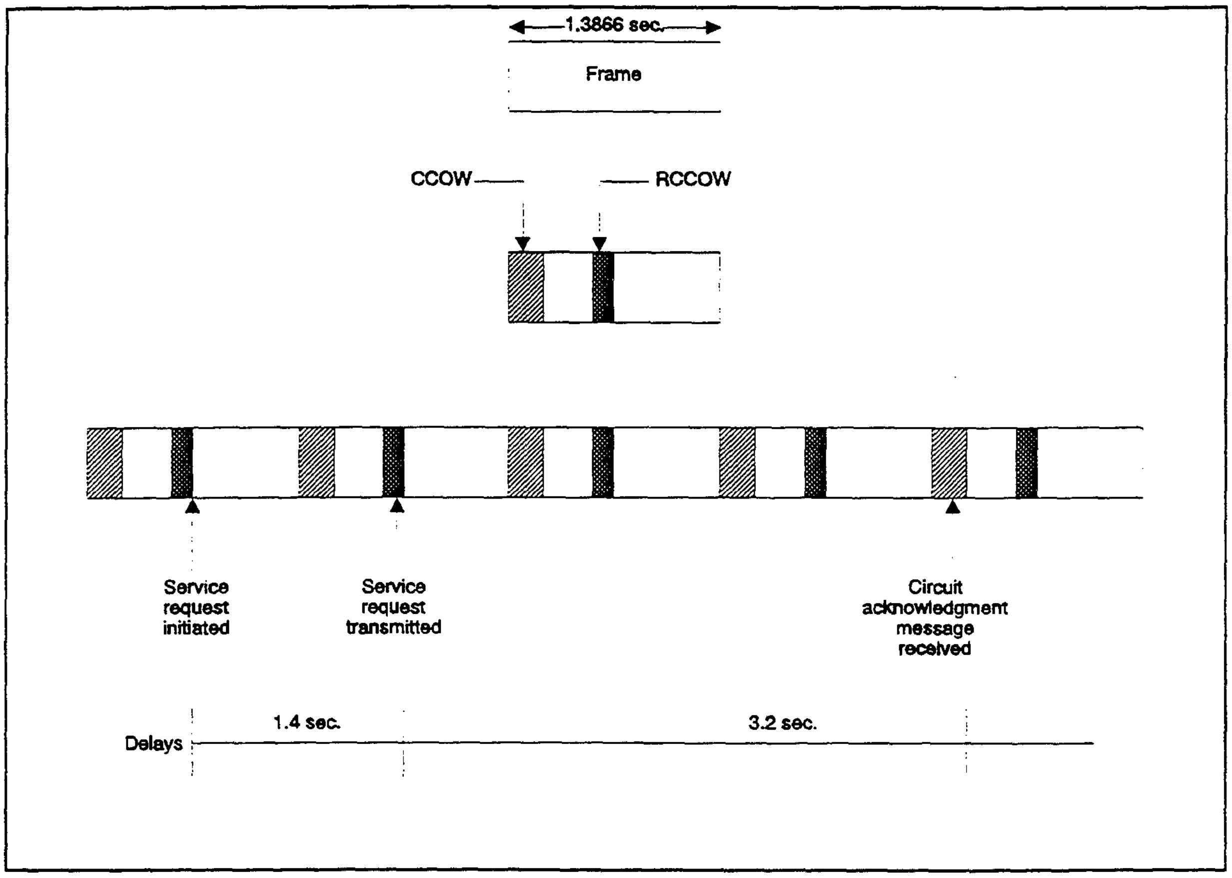


Figure 3-4. 25-kHz Waveform Link Set-up Delay

dedicated to another terminal by the DAMA controller; (2) the RCCOW slot is required to respond to a DAMA controller channel control request; or (3) the frame precedence, which is assigned by the DAMA controller, is greater than the precedence of the

RCCOW. These delays depend on traffic loading statistics and cannot be projected without extensive modeling.

Figure 3-4 delays assume lack of collisions and other delays in accessing the RCCOW, and the DAMA controller can assign time slots for the requested communications. The service request initiation is noted on the left side of the figure. Based on the point in the TDMA frame that this request is made, there could be a 1.4-second delay. This delay could be minimal if the request were provided to the terminal just prior to the occurrence of the RCCOW. The service request would be transmitted in the first available RCCOW. This service request would be acknowledged via a CCOW transmission and received at the terminal within the third frame after transmission of the RCCOW service request. This would result in a 2-frame delay (2.8 seconds) plus the time between the RCCOW and the start of the CCOW (.37 seconds). Therefore, a delay of between 3.2 and 4.6 seconds would be experienced between service request initiation and the start of communications.

In the event of a collision on the RCCOW, the terminal waits 3.2 seconds for an acknowledgment that will not be received. If an acknowledgment is not received, the terminal selects a future frame to retransmit the service request. Appendix B discusses the delays associated with retransmission of additional service requests.

Other delays that can be experienced in link setup are indicated below:

- There are limits placed on the use of the RCCOW through an assignment method in the CCOW, which makes these slots unavailable for service requests. An example is when a terminal is requested to send a status report. This request must be responded to in

the next frame. This introduces an additional delay for initiating a service request, and these delays depend on traffic statistics.

- Delays are experienced for those cases when the called party is busy or the DAMA controller is processing service requests of higher priority. In this case, the DAMA controller advises, in the Call Acknowledgment message, that the call has been placed in a queue. When placed in the queue, the CCOW message includes the time delay until the call can be serviced. This time varies, based on traffic load, priority of service requests, how busy the called party is with equal or higher-priority service requests, and whether the called party has logged off the air for a preset time. Should this occur, the DAMA controller will process the request as soon as time slots are available.

- The DAMA controller can limit the call requests to those above a certain priority within specific frames. The delays associated with this restriction depend on traffic statistics. Should this occur, the terminal maintains the call in a queue for processing when time slots are available.

Note that if the standard were changed to permit the controller to respond to a request for service in the next frame instead of waiting for the third frame to respond, the link setup delay could be reduced to 3 seconds.

3-3 WAVEFORM DELAYS

This paragraph addresses the delays that would be experienced between the time one user finishes talking and the spoken words are received by the called party. These delays are caused by the TDMA frame structure, which requires that the data bits resulting from voice digitization be buffered for insertion into the designated TDMA time slot.

The user data stream, following analog-to-digital conversion at 2400 bps, is input to a buffer for transmission at the proper time sequence within the TDMA frame. This user data is integrated with overhead information for proper operation and transmitted at the start of the designated TDMA time slot. At the receive end the overhead bits are removed and the user telephone is provided with a data stream at 2400 bps. This buffering delay applies only to the TDMA/DAMA mode.

A. 5-kHz Waveform Delays. The delays for this waveform are 8.96 seconds. Interactive voice delay, which is that time between talking and hearing the response from the called party are completed, would be 17.9 seconds. This delay is an impediment to operations. For example, roll call for a net of 5 users would take almost 2 minutes to ensure everyone was on line. In addition, net discipline would be critical to prevent everyone from talking at the same time.

B. 25-kHz Waveform Delays. The delays for this waveform are 1.3866 seconds. Interactive voice delay is 2.7 seconds.

3-4 TOTAL DELAYS

Table 3-2 presents the results of the delays that will be experienced for voice services defined in MIL-STDs 188-181/182/183. The first two columns depict the voice service options available for both the 5- and 25-kHz channels and reflect

use of optional orderwires to set up the circuit. This optional use of orderwires is discussed in Chapter 2. The voice service options are for 2.4- or 16-kbps voice, as noted. Note that the link set-up delays are based on which orderwire is being employed and results in a 6-fold decrease with use of the 25-kHz orderwire. The waveform delays on the other hand are determined by the waveform's being used for actual communications. The delays shown constitute the extra time required above the time experienced when operating in the dedicated mode, as is now done. Transmission delay (earth terminal to satellite to earth terminal) and terminal installation times are not included in Table 3-2. All delays have been rounded off to the nearest tenth of a second.

We can conclude from Table 3-2 that the Link Setup and Waveform delays of the 5-kHz TDMA/DAMA are excessive for voice service, and many users have stated that these delays will not meet their requirements. In addition, the 5-kHz TDMA/DAMA mode does not provide high efficiencies when it is used for voice. Therefore, the Joint Interoperability and Engineering Organization (JIEO) feels that 5-kHz TDMA/DAMA voice services should never be allocated to high-priority users (for example, communications higher than *priority*). Furthermore, low-priority users should be assigned voice services on 5-kHz TDMA/DAMA only when other modes are not available and only when channel reconfiguration will introduce inefficiencies or interferences to low-speed circuit and message traffic. This JIEO position will be coordinated and will be formalized and incorporated in MIL-STD-188-185, the DAMA Management and Control standard, which is now being developed.

Table 3-2 UHF DAMA Delays

CHANNEL (kHz)	ORDERWIRE USED (kHz)	MODE	DATA RATE (kbps)	WAVEFORM ACQUISITION DELAY NO COLLISIONS (SECONDS)	LINK SET-UP DELAY NO COLLISIONS (SECONDS)	WAVEFORM DELAY (SECONDS)
25	25	TDMA/DAMA	2.4	1.5 to 12.7	3.2 to 4.6	1.4
25	25	TDMA/DAMA	16	1.5 to 12.7	3.2 to 4.6	1.4
25	25	DASA	16	1.5 to 12.7	3.2 to 4.6	0
25	5	DASA	16	27 to 36	18 to 27	0
25	Not Required	Dedicated	16	0	0	0
5	25	DASA	2.4	1.5 to 12.7	3.2 to 4.6	0
5	5	TDMA/DAMA	2.4	27 to 36	18 to 27	9
5	5	DASA	2.4	27 to 36	18 to 27	0
5	Not Required	Dedicated	2.4	0	0	0

CHAPTER 4

ACCESS AND ALLOCATION OF UHF SATCOM RESOURCES

This chapter presents the access utilization procedures and how they affect user resource allocation. It provides a brief overview of the UHF SATCOM DAMA management and control concept and a discussion of the problem of resource allocation for the DAMA system. A solution to this problem is proposed, using an apportionment method for allocating UHF SATCOM resources to user organizations, and an example of the application of the apportionment method is presented.

4-1 BACKGROUND

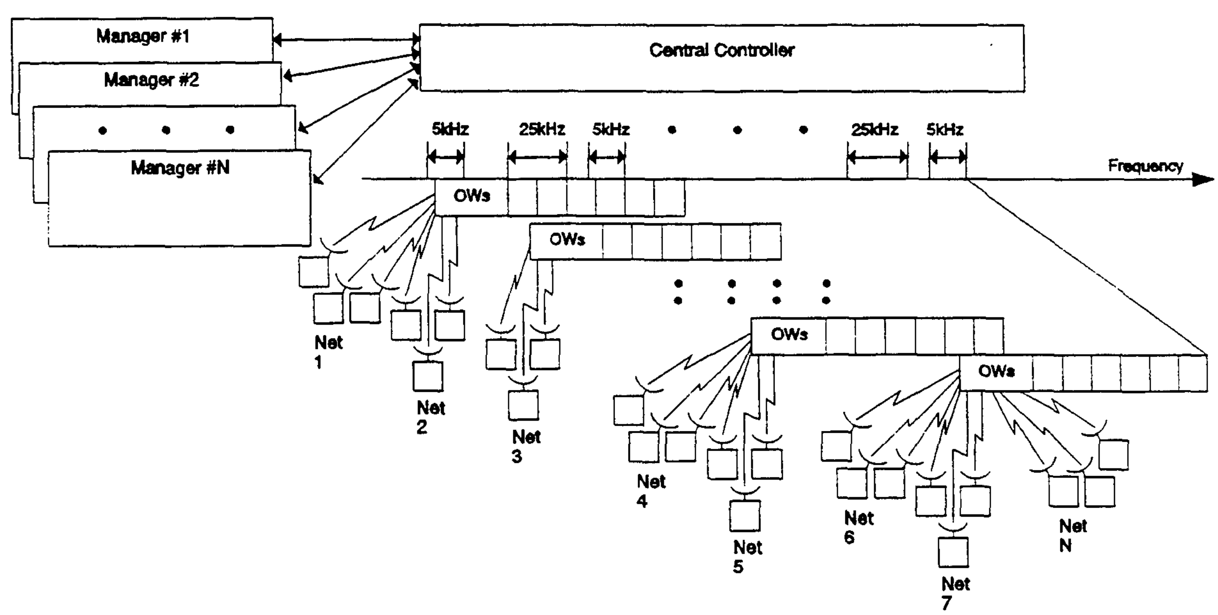
MIL-STD-188-185 will define the management and control concepts for the UHF DAMA system. The control and management of the satellite systems is defined as follows:

- Control System - Executes the management and control plans established by the resource manager. The control system consists of equipment, procedures, and manpower that configure satellite channels and assign access.

- Resource Management - Encompasses planning functions and provides direction to the DAMA system controller to allocate satellite DAMA resources.

After a study and several Joint working-group sessions, during which several alternative management and control concepts were evaluated and discussed, the Joint Staff directed JIEO to incorporate, into MIL-STD-188-185, a decentralized management and centralized system control concept, in accordance with option C of Reference F. This direction was issued in a Joint Staff memorandum to JIEO, dated 24 November 1993.

The centralized system control and decentralized resource management concept entails having all UHF SATCOM channels in each footprint under one access system controller. The access system controllers for each footprint are tied together and connected to a central processing facility, which houses the management and control database. The access system controllers are under the jurisdiction of several authorities that provide management directions for the space segment resource allocation through their entries into their parts of the central database. The system diagram for this concept is presented in Figure 4-1.



CONCEPT: All channels (in each footprint) are under one access system controller. The access system controller is under the jurisdiction of several authorities that provide management directions for space segment resource.

Figure 4-1. Centralized System Control and Decentralized Management

As illustrated in the figure, all user nets for the commanders in chief (CINC), Services, and Agencies (C/S/A) gain access to the system via a central controller. The management functions, however, are performed by each organization's resource manager, who allocates services via priorities to users within the C/S/A organizations. The resource management functions are spread at different levels from the Joint Chiefs of Staff (JCS) level down to the unit level. As described in the Concept of Operations (CONOPS) for Management and Control of DAMA Systems [Ref.I], the entire satellite resources in a footprint will be represented as a "pie." JCS will allocate SATCOM services to the CINCs by apportioning to each CINC a piece of the SATCOM pie, as illustrated in Figure 4-2. The question is "What are apportioned, satellites, channels, and time-slots, etc?" This question is addressed below.

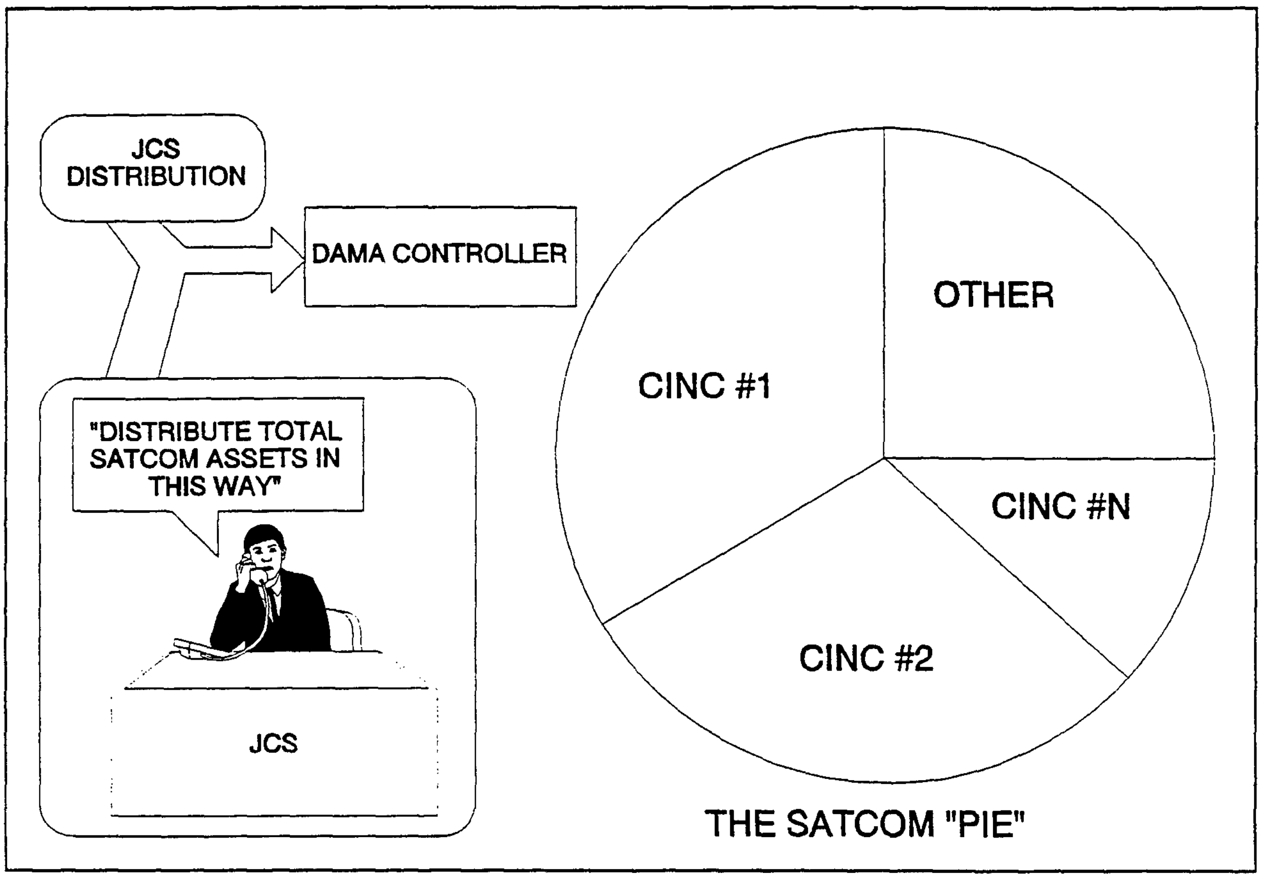


Figure 4-2. JCS Apportionment of SATCOM "Pie"

4-2 RESOURCE ALLOCATION PROBLEM

The problem of allocating resources within the UHF DAMA operation is very complex. The complexity is introduced by the transition of a "dedicated channel mentality" to a "shared service mentality." Recalling the hotel example in Chapter 2 that was used for explaining DAMA services, we can easily see that there can be various degrees of dedicated floors, shared floors, and shared rooms. The problem arises in figuring out how many different users can be served. For example, if the hotel had 100 rooms, 100 people could take a trip and be accommodated at the same time. Does that mean that the served clientele are limited to only 100 people? No, thousands of people can be customers during the year, but they all cannot be there at the same time. It is the same with DAMA, but there is an additional feature that really helps with serving users. It is called *priority level.* Each user or net can be assigned a priority level from 1 to 5, as follows:

Priority 1 - FLASH OVERRIDE
Priority 2 - FLASH
Priority 3 - IMMEDIATE
Priority 4 - PRIORITY
Priority 5 - ROUTINE

The number of priority 1's given out must equal the resources, so that in the unlikely event that all of these priority 1 users need to communicate at the same time, they can. The priority 1 users are those who have the dedicated channels today. However, when they are not using the resources, lower-priority users can. If a high-priority user needs to communicate when all of the resources are busy, the lowest-priority user assigned those resources is preempted.

The DAMA planners realized that there are special situations and special requirements that will preclude a user

from operating in the TDMA/DAMA waveform. That is why a user can be assigned a dedicated channel when he needs it. A user can be given a dedicated channel on a shared basis, if he can live with the set-up delays defined in this tutorial. Acceptable voice service and great data-transfer services can be provided in the TDMA/DAMA mode, if the users can live with the slight set-up constraints discussed. If all the SATCOM channel resources were shared in the TDMA/DAMA mode, at least 20 times the number of users could be served, compared to dedicated channel assignments. However, if some of the channels are assigned to dedicated users, the reduction in the number of users that can be served is not proportional. For example, if ten 25-kHz channels were available to share among TDMA/DAMA voice users, 390 users could be provided service. If 3 channels of the 10 were dedicated to special users, only 7 would be left to share among other users. The remaining 7 channels could serve only 259 users. The total number of users served is now 3 dedicated plus 259 shared. Therefore, reducing the shared number of channels by 3 causes the number of users served to drop by 128. (See REF.E for further details on DAMA traffic-handling capacities.)

So the problem is to allocate a mixed set of services, because in the real world, some users must have a dedicated channel, some will be happy with sharing a pool of dedicated channels (DASA), some will have their needs met by sharing time slots on the waveforms, and still others will be extremely grateful to get any kind of UHF SATCOM access at all. One possible solution to this problem is through the assignment of points for various types of SATCOM services. This system is called the *point allocation system.* Since the DAMA system is extremely flexible in its configuration, and will be controlled by an overall management system that will be hierarchical from JCS to CINC to Service component to unit, the proposed resource allocation system will allow commanders to decide the configuration of their assigned resources, based on an

apportionment of points, which will constitute their piece of the SATCOM Pie.

4-3 PROPOSED POINT ALLOCATION CONCEPT

The basis of this proposed point allocation concept is not to assign an organization a satellite, a channel, or a time slot for communications, but rather to allocate a number of service points to the organization. Points can be considered "money" for buying SATCOM services. The organization would "spend" these points to buy the types of services it needs to satisfy its mission. With this method, each type of service would be defined and assigned a point value. The point value would represent the capacity that is subtracted from the total network capacity when a user selects it. The entire system would have a total point capacity. Each satellite footprint would have a total capacity of points that would be color-coded. The color codes are required to permit the "purchase" of a mix of services on the two different DAMA waveforms. Four colors could be used to represent the four basic resources:

5-kHz single-access channel
25-kHz single-access channel
5-kHz TDMA/DAMA
25-kHz TDMA/DAMA

The colors help distribute the services among the users and prevent any one particular resource from being oversubscribed. For example, if the points were not color-coded, nothing would prevent all users from purchasing all 5-kHz DASA channels, which could not be accommodated by the system. Using Table 4-1, with no colors and 20,000 points per footprint, the system would need to provide one hundred 5-kHz channels, but only 44 would be available per footprint, and the other resources would be undersubscribed (barely used for priority 1).

The total number of points allocated to user organizations in this footprint cannot exceed the total point capacity, or services will be oversubscribed. To illustrate, let us assume that each footprint has 5,000 each of Green, Blue, Yellow, and Red points. Example point values for the various SATCOM services are provided in Table 4-1. The numbers in this table are based on some preliminary calculations as to the relative service capacities consumed from the total network when each service is selected.

Table 4-1 Sample Point Allocation Table

SERVICE NUMBER	UHF SATCOM SERVICE	POINTS
1	DASA on 25-kHz channel	500 Green or Blue
2	DASA on 5-kHz channel	200 Green only
3	16-kbps circuit	350 Green or Blue
4	4.8-kbps circuit	200 Green or Blue
5	2.4-kbps circuit	90 Green, Blue, or Yellow
6	1.2-kbps circuit	60 any color points
7	600-bps circuit	40 any color points
8	300-bps circuit	25 any color points
9	75-bps circuit	15 any color points
10	TDMA/DAMA message service	10 any color points

The table lists the service number, the service offered, and the point and color value to "buy" that service. Each organization is allocated a number of colored points. Notice that some of the services can be bought only with Green points and others can be bought with any color points. It should also be noted that the services are not mutually exclusive; that is, if an organization buys a service, it is entitled access to that service and all services with an equal or lower point value. The

point values represent those required to buy priority 1 service or "assured access" service.

Points allocated to an organization can be used by that organization and/or can be allocated to subordinate units for their use. For example, if an organization were assigned 1,000 Green points, and it decided to use 500 points to give one of its user nets with 1 DASA 25-kHz channel, that user net would also be entitled access to services 2 through 10.

The organization might also use the remainder of the points to buy a 1.2-kbps circuit service and a 600-bps circuit service, and allocate 200 points to each of 2 subordinate units. Many other combinations of services exist that would add up to 1,000 points. It would depend on the number of user nets that the organization needed to satisfy, the type of services they required to complete their missions, and the number of subordinate units to which they had to allocate SATCOM service. These nets would all be priority 1 nets and would have assured access. Other user nets within the organization can be assigned service at a lower priority, as described below.

To illustrate how precedence and preemption is integrated into the allocation concept, consider how one of the subordinate units could use its allocated points. As mentioned earlier, priority 1 users are those who will have assured access to SATCOM services. Other users in the unit are assigned lower-priority levels by taking the number of priority 1 points and applying a multiplier to calculate the number of points that can be assigned for that priority level. The multipliers serve two important purposes: (1) they force users to group their nets into separate groups with distinct priorities, rather than grouping them all in one priority, and (2) they allow users to access more expensive services on a lower-priority basis, which they otherwise would not be able to afford at all. Below are the multipliers:

Priority 1 - 1.00
Priority 2 - 1.25
Priority 3 - 1.50
Priority 4 - 2.50
Priority 5 - 5.00

Using this convention, the unit that was allocated 200 Green points could assign user nets the following configuration:

- Priority 1 user nets (1 x 200 = 200 points)
  one 5-kHz DASA channel service (200 points)

- Priority 2 user nets (1.25 x 200 = 250 points)
  two 2.4-kbps circuit service (180 points)
  one 600-bps circuit service (40 points)
  one 300-bps circuit service (25 points)

- Priority 3 user nets (1.5 x 200 = 300 points)
  two 2.4-kbps circuit service (180 points)
  two 1.2-kbps circuit service (120 points)

- Priority 4 user nets (2.5 x 200 = 500 points)
  one 25-kHz DASA channel service (500 points)

- Priority 5 user nets (5 x 200 = 1000 points)
  one 25-kHz DASA channel service (500 points)
  four 2.4-kbps circuit service (360 points)
  two 1.2-kbps circuit service (120 points)
  two 600-bps circuit service (80 points)

This unit can assign 19 nets with SATCOM access, using the DAMA point allocation method. Under the old single-net-per channel method, only one net would have access. The DAMA system, coupled with this point allocation method, allows more users in this unit to access SATCOM services and still provides the priority 1 assured access net that would have been allotted under

the old method. In addition, notice the vast range of services available to the other user nets. A priority 5 user net can get access to a full 25-kHz channel and send 16-kbps data during off-peak traffic hours (when least likely to get preempted), where under the old system, there would not be a chance for access to this type of service.

4-4 ALLOCATION EXAMPLE

This section presents an example of the proposed DAMA point allocation method. It illustrates the allocation of points from the JCS to the CINCs, from the CINCs to the component commands, and from the components to the units. The sample organizational structure is presented first, followed by the sample application of the point allocation concept.

A. Sample Organization. The sample organization is representative of a satellite footprint with three CINCs, similar to the Indian Ocean area of operations. Figure 4-3 presents the

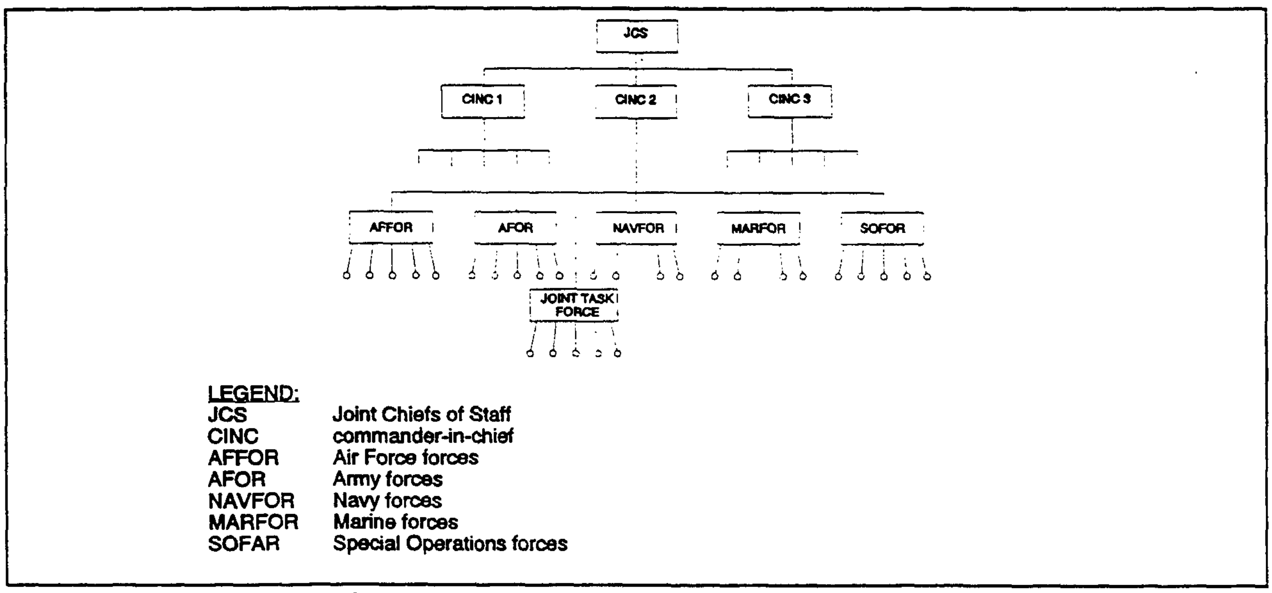


Figure 4-3. Sample Organization

organizational structure from JCS through the CINC, component, and unit forces. To provide a generic organizational structure,

we have labeled the three CINCs as 1, 2, and 3, and each CINC has 5 components with the option of a sixth joint task force (JTF).

B. Service Allocation Example. Referring to the sample organizational structure, the JCS has 20,000 points (5,000 of each color) to allocate within this footprint. Each organization has an account and cannot spend more than is in that account. Point allocation adjustments can be negotiated with the allocating organization, and, therefore, trading of point resources can also be arranged so that subordinate elements can have their requirements met. The distribution of these service points is described below.

1. JCS Allocation and Distribution of Service Points. The JCS has a "UHF SATCOM service account" with 5,000 each of Blue, Green, Yellow, and Red points. The JCS will most likely hold points in reserve for special contingencies and assign a national command authority (NCA) net, which could include the White House, the JCS, and all of the CINCs in the footprint. This net would likely be a 25-kHz DASA channel. The remaining points would be allocated to the CINCs. Therefore, if the JCS keeps 10% of the points in reserve and sets up the NCA net, and then allocates to the CINCs the rest of the points, the JCS account will be as follows:

JCS UHF SATCOM ACCOUNT

ITEM	BLUE	GREEN	YELLOW	RED
Initial Deposit	5,000	5,000	5,000	5,000
one 25-kHz DASA	-500	--	--	--
CINC1	-1,000	-1,500	-1,500	-1,500
CINC2	-1,500	-1,500	-1,500	-1,500
CINC3	-1,500	-1,500	-1,500	-1,500
Balance	500	500	500	500

Note that in addition to the 500 points of each color held in reserve by the JCS, nets of lower priority can be set up using the 500 Green points assigned as priority 1. The points available for assignment in other priorities are Green points of 625 priority 2, 750 priority 3, 1,250 priority 4, and 2,500 priority 5. CINC2 will be used to continue the allocation example.

2. <u>CINC2 Allocation and Distribution of Service Points</u>. This CINC has 1,500 each of Blue, Green, Yellow, and Red points and will likely set up a command and control (C2) net, a component net, an NCA net, an intelligence (INTEL) net, and others as appropriate. The CINC may decide to set up his C2, component, and INTEL nets on a 5-kHz DASA channel, and his NCA net on a 25-kHz DASA channel. The CINC can then allocate the rest of his points to his subordinate components. CINC2's account is as follows:

CINC2's UHF SATCOM ACCOUNT

ITEM	BLUE	GREEN	YELLOW	RED
Initial Deposit	1,500	1,500	1,500	1,500
one 25-kHz DASA	-500	--	--	--
three 5-kHz DASA	--	-600	--	--
AFFOR	--	-200	-300	-300
AFOR	--	-200	-500	-300
NAVFOR	-500	--	-100	-300
MARFOR	--	-200	-300	-300
SOFOR	-500	--	-300	-300
Balance	0	100	0	0

CINC2 has 100 Green points in reserve. He can also assign to his support staff the following numbers of points in lower-priority services:

	BLUE	GREEN
Priority 2	625	750
Priority 3	750	900
Priority 4	1,250	1,500
Priority 5	2,500	3,000

The allocation of points continues with each component assigning the nets that they require from their allocated points, and allocating the remainder to their subordinate units. The example will continue with AFOR.

3. AFOR's Allocation and Distribution of Service Points. AFOR sets up five nets with its allocated points, and allocates points to three of its subordinate units.

AFOR's UHF SATCOM ACCOUNT

ITEM	NET NAME	GREEN	YELLOW	RED
Initial Deposit	--	200	500	300
one 5-kHz DASA	Net 1	-200	--	--
one 2.4-kbps circuit	Net 2	--	-90	--
one 2.4-kbps circuit	Net 3	--	-90	--
one 2.4-kbps circuit	Net 4	--	-90	--
one 2.4-kbps circuit	Net 5	--	-90	--
Unit 1	--	--	-90	--
Unit 2	--	--	--	-150
Unit 3	--	--	--	-100
Balance	0	0	50	50

AFOR keeps 50 of Yellow and Red points in reserve. AFOR can assign lower-priority nets to lower-priority users by employing the priority multipliers, as described earlier. The units that were allocated points from AFOR will also have a UHF SATCOM account to set up nets and allocate points to their subordinate units.

4-5 NETWORK-ACCESS CLASS OF SERVICE

A description of user access would not be complete without discussing the network access class of service (COS) that must accompany the assignment of nets. The controller must have in its database the call priorities allowed for each user on the network for varying conditions. Two kinds of network access COSs must be defined:

- Individual COS - Defines the highest precedence with which an individual can place a call to an individual user or undefined net.

- Net COS - Defines the highest precedence that may be used by any individual in a defined net to establish a call to the net.

Using some of the nets assigned in the example above, these COSs can be illustrated. The JCS NCA net defined in the example would be assigned a net COS of priority 1, meaning that when a user who is defined as a member of that net initiates a call to that net, the precedence used to set up the net call is FLASH OVERRIDE (FO), regardless of what his individual COS may be. When this net was defined in the network, it cost the proponent, who was JCS, 500 Blue points.

In contrast, suppose CINC2 set up his C2 net as an individual COS of priority 1, meaning that he can dial up any of his subordinates and talk to them individually, rather than have them all on the same net. This supposes that he has defined his component net to allow him to talk to all component commanders at once. This component net has a net COS of priority 1. CINC2's configuration means that individual subordinate commanders cannot call CINC2 privately with a precedence of FO unless they set up an individual COS of priority 1. They could call him on the CINC2 component net, but they would activate the entire net, and it would not be a private call.

Of course, as was illustrated above, expended priority 1 points are multiplied for lower priorities, and these lower-priority points may be used to assign individual COSs to various users who talk to many different individuals, rather than the same net all of the time. They may also be used to buy services that could not be bought at a higher priority. The point allocation system provides a great deal of flexibility in

assigning services and satisfying a wide range of user situations and requirements.

APPENDIX A

DELAYS IN WAVEFORM ACQUISITION WITH COLLISIONS

A-1 INTRODUCTION

This appendix discusses the time delays experienced when collisions occur in gaining access to time slots in the TDMA waveform used for waveform acquisition and the 5-kHz network login. Based on the a priori knowledge of where the time slots are located, each earth terminal transmits in one of these time slots without coordinating with other earth terminals. Without coordination, two or more earth terminals can experience collisions. Collisions occur when two or more earth terminals transmit on the same time slot that is available for access by any earth terminal. Collisions during terminal set up can be experienced on the two waveforms as follows:

- 5-kHz. Uplink acquisition (ranging) on the ROW contention-ranging time slots and login on the contention ROW message time slots.

- 25-kHz. Uplink acquisition (ranging) on the ranging time slots.

When collisions occur, procedures are essential to reduce the possibility of collisions on subsequent retransmissions. Each terminal waits for some future frame to retransmit; but if this delay is not random on the part of each terminal, each retransmits on the first available time slot in the first available frame, resulting in further collisions. This random process is discussed for each waveform.

A-2 5-kHz WAVEFORM ACQUISITION DELAYS WITH COLLISIONS

A. Uplink Acquisition. The 5-kHz waveform has contention-ranging time slots allocated in the ROW segment of the TDMA waveform, which are used by terminals to initially enter the DAMA network. The number of these time slots in each frame is variable, based on assignment by the DAMA controller. The number of contention-ranging time slots in each frame can be 1, 2, 4, 8, 12, or 16. Each earth terminal is advised of the number of these time slots via a field in the FOW. The following explains actions taken by the terminal from the time the collision is detected until the follow-on retransmissions are made.

1. The acquisition backoff number is determined based on whether the transmission is the first or subsequent retransmission of the ranging signal. The number is 2 for the initial retransmission and 5, 10, 50, 100, or 250, in the order shown, for subsequent retransmissions.

2. A uniformly distributed random number between 1 and the acquisition backoff number, inclusive, is generated.

3. At the frame immediately following the first ranging attempt, the terminal starts counting the number of contention-ranging time slots that occur.

4. The future frame for retransmission of the ranging signal is determined when the accumulated number of contention-ranging time slots equals or exceeds the random number generated by the terminal.

5. The terminal also generates a uniformly distributed random number between 1 and the number of contention-ranging time slots available in the frame determined in 4, above.

6. The terminal transmits the ranging signal within the frame determined in 4, above, in the contention-ranging time slot of that frame equal to the number generated in 5, above.

The delay between the initial transmission and retransmission is a function of (1) whether the retransmission is a first or subsequent attempt, which determines the acquisition backoff number to be used; (2) the random number generated by the earth terminal, which determines how many contention-ranging time slots must accrue before retransmission; and (3) the number of contention-ranging time slots in each frame.

The first retransmission occurs with only a 9-second delay, regardless of the number of contention-ranging time slots in each frame. If the random number generated by the terminal is 1, the terminal only has to count 1 contention-ranging time slot before retransmission. Since the ROW has a minimum of 1 such slot in each frame, this count is accrued in the next frame. If the terminal generates 2 as the random number, and there is only 1 contention-ranging time slot in both frames, it retransmits in the second frame for an 18-second delay. Where there is more than one contention-ranging time slot in the frame, additional randomness is provided for by the second number generated by the terminal, which determines in which time slot the ranging will be done. If the second transmission experiences a collision, the terminal increases its backoff number to 5 and repeats the procedure by selecting a random number between 1 and 5. With each collision, the backoff number is increased until ranging is successful.

Table A-1 shows the delays that would be experienced for each acquisition backoff number, and therefore retransmissions, assuming a fixed assignment of 1, 8, or 16 contention-ranging time slots per frame. The delays shown are in seconds and reflect least- and worst-case delays, based on the earth terminal generated random number. The delays shown in

Table A-1 do not take into account the actual time slot within the frame.

Table A-1 Ranging Delays with Collisions

NUMBER OF CONTENTION-RANGING TIME SLOTS PER FRAME	ACQUISITION BACKOFF NUMBER									
	5 2nd Try		10 3rd Try		50 4th Try		100 5th Try		250 6th Try	
1	18	54	27	135	36	576	45	1467	54	3708
8	18	18	27	36	36	99	45	211	54	491
16	18	18	27	27	36	63	45	126	54	270

The least delay (left column for each backoff number) is based on the earth-terminal-generated number that is 1, and the worst case is an earth-terminal-generated number is equal to the acquisition backoff number. For example, for a backoff number of 5, with 1 contention-ranging time slot per frame, the least delay would occur if the terminal-generated number were 1. This would result in the subsequent frame selected for retransmission, or a 9-second delay, added to the delay of 9 seconds for the first failed retry. The worst case would be a terminal-generated number of 5. This would result in an additional 4-frame or 36-second delay. Note that regardless of backoff number, the additional delay is minimal (9 seconds) if the terminal-generated number is 1. In addition, note that the number of contention-ranging time slots has a significant effect on delays.

The worst-case scenario that increases the potential for collision on the contention-ranging time slots is all networks attempting to enter the DAMA network following an outage of the DAMA controller. This potential for collision is increased if none of the terminals can do passive ranging, all

terminals have been off the air long enough to lose TDMA synchronization, and there is urgency in reconstituting networks to respond to a crisis. To compensate for this condition, the DAMA controller can increase the number of contention-ranging time slots per frame. Note also that the random process used, which is done independently by each earth terminal, enhances the probability that collisions will not occur.

B. Login Delays with Collision. A terminal assumes that a transmitted login request was lost by the DAMA controller if an acknowledgment is not received within 4 frames (36 seconds). Should this occur, the terminal automatically retransmits the login request after a random delay. The number of contention ROW time slots in each frame used for forwarding login requests is variable, based on DAMA controller assignments. Each terminal must determine the number of these time slots from information in the FOW segment. The following describes the steps taken between the time a collision is experienced and the time the login request is retransmitted:

1. The terminal looks up the ROW contention backoff number provided by the DAMA controller in the FOW. This backoff number can be 1, 30, 60, 250, or 1,000.

2. A uniformly distributed random number between 1 and the backoff number, inclusive, is generated.

3. Starting at the next frame, the number of contention ROW time slots is counted.

4. In the frame where the accumulated number of contention ROW time slots equals or exceeds the random number generated in (2) above, the retransmission is made.

5. Another random number between 1 and the number of ROW contention-ranging time slots in the frame determined in (4), above, is generated.

6. In the frame determined in (4), above, the terminal retransmits the login request in the time slot determined in (5), above.

The delay between initial transmission of a login message and subsequent retransmission is a function of (1) the contention ROW backoff number; (2) the terminal-generated random number; and (3) the number of contention ROW time slots per frame, which is variable frame-to-frame, based on DAMA controller assignments.

Table A-2 lists the delays experienced in automatically retransmitting a login message. The delays shown do not reflect the 36-second delay between transmission of the initial login request and lack of receipt an acknowledgment within 4 frames. Table A-2 lists delays for each contention ROW backoff number and gives the best- and worst-case delay for when there are 5 or 11 contention ROW time slots per frame. The best case applies when the earth-terminal-generated random number is 1. The worst case is when the earth terminal generates a random number equal to the backoff number. For example, the best-case delay for a backoff number of 60, assuming there are 5 contention ROW time slots per frame, is 9 seconds. This is based on the terminal's generating a random number of 1. In this situation, the retransmission occurs in the frame following initial transmission. The worst case is based on the terminal's generating a random number of 60. In this case, the delay is 108 seconds.

Table A-2 Login Delays with Collisions

NUMBER OF CONTENTION ROW TIME SLOTS PER FRAME	CONTENTION ROW BACKOFF NUMBER									
	1		30		60		250		1000	
5	9	9	9	54	9	108	9	450	9	1791
11	9	9	9	27	9	54	9	207	9	819

A-3 25-kHz WAVEFORM ACQUISITION DELAYS WITH COLLISIONS

The 25-kHz waveform has a segment of the TDMA waveform allocated for contention ranging called the *Range* segment. This segment is used by earth terminals to initially enter the DAMA network.

The range time-slots in the waveform provide almost 1,300 ranging opportunities per hour in the odd-numbered frames. With this many ranging slots available and assuming that 1 terminal is ranging every minute, there would be only a 1 in 21 chance of collision. The following explains actions taken by the terminal from the time a collision is experienced until follow-on retransmissions are made:

1. A random number Y between 1 and 128 is generated.

2. The terminal waits $2Y$ frames and retransmits.

3. If the first retransmit is unsuccessful, the terminal waits $256-2Y$ and generates another random number Z between 1 and 128.

4. The process is repeated.

Table A-3 shows the delays that occur between the initial unsuccessful ranging transmission and subsequent retransmission.

The time shown reflects the cumulative time from the initial ranging attempt.

Table A-3 Delay in Acquisition with Collisions

	First Retransmit		Second Retransmit		Third Retransmit	
	Min	Max	Min	Max	Min	Max
Delay In Seconds	2.8	358	361.2	716	719.6	1074.4

APPENDIX B

DELAYS IN SERVICE REQUEST RESPONSE WITH COLLISIONS

B-1 INTRODUCTION

This appendix discusses the delays experienced in gaining access to time slots in the TDMA waveform used to forward service requests from the terminal to the DAMA controller. Based on a priori knowledge of where these time slots are located, each earth terminal selects and transmits on a specific time slot without coordinating with other earth terminals. Without this coordination the service request can be lost due to collisions. Collisions occur when two or more earth terminals transmit in the same time slot that is available for access by any earth terminal. Should this message loss occur, procedures are essential to reduce the possibility of collisions on subsequent transmissions of the service request. Each terminal waits for some future frame to retransmit, but if the delay is not random on the part of each terminal, each transmits on the first available time slot in the first available frame. Again, the requests are lost. The manner in which the earth terminals manage these random retransmissions is discussed for each waveform.

B-2 5-kHz LINK SET-UP DELAYS WITH COLLISIONS

A terminal assumes that a transmitted service request was lost by the DAMA controller if an acknowledgment is not received within 4 frames (36 seconds). Should this occur, the terminal automatically retransmits one service request after a random delay. The number of contention ROW time slots in each frame used for forwarding service requests is variable, based on DAMA controller assignments. Each terminal is advised of the number and location of these time slots via an FOW message. The following describes the steps taken between the time a collision

occurs and the time the service request is automatically retransmitted:

A. The earth terminal looks up the ROW contention backoff number provided by the DAMA controller in the FOW. This backoff number can be 1, 30, 60, 250, or 1,000.

B. A uniformly distributed random number between 1 and the backoff number, inclusive, is generated.

C. Starting at the next frame, the number of contention ROW time slots is counted.

D. At the point where the number of contention ROW time slots equals or exceeds the random number generated in B, above, is the frame used for retransmission.

E. Another random number between 1 and the number of ROW contention time slots in the frame determined in D, above, is generated.

F. In the frame determined in D, above, the terminal retransmits the service request in the time slot determined in E, above.

The delay between initial transmission of a service request message and subsequent retransmission is a function of (1) the contention ROW backoff number; (2) the terminal-generated random number; and (3) the number of contention ROW time slots per frame, which is variable frame-to-frame, based on DAMA controller assignments.

Table B-1 lists the delays experienced in the automatic retransmission of one additional service request message, based on the ROW backoff number and the number of contention ROW time slots. This table lists delays for each contention ROW backoff

Table B-1 Service Request Delays with Collisions

NUMBER OF CONTENTION ROW TIME SLOTS PER FRAME	CONTENTION ROW BACKOFF NUMBER									
	1		30		60		250		1000	
5	9	9	9	54	9	108	9	450	9	1791
11	9	9	9	27	9	54	9	207	9	819

number and gives the best- and worst-case delay for the condition in which there are 5 or 11 contention ROW time slots per frame, not including the 36-second delay between transmission of the initial service request and not receiving an acknowledgment. For example, the best-case delay for a backoff number of 60, assuming there are 5 contention ROW time slots per frame, is 9 seconds. This is based on the terminal's generating a random number of 1. In this situation, the retransmission would occur in the frame following initial transmission. The worst-case delay, for the same conditions, is based on the terminal's generating a random number of 60. In this case, the delay is 108 seconds (60 x 9/5).

Note that the least delay is experienced when the terminal-generated random number is 1 for a constant number of contention ROW message time slots per frame. The most delay for the same conditions are experienced when the earth-terminal-generated number is equal to the backoff number. Note also the effect of the number of contention ROW time slots per frame. Doubling the number of these time slots reduces the delay time by a factor of 2.

Following this additional automatic retransmission of the service request, additional retransmissions will require operator action.

B-3 25-kHz LINK SET-UP DELAYS

The information presented in this section is based on an interpretation of paragraph 5.2.2.3.3 of MIL-STD 188-183. This section should be reviewed thoroughly to clarify the procedures contained therein. The procedure for initial RCCOW transmission, as well as the number of retransmission attempts, are only two of the items requiring clarification. Others include the selection of random wait times and the specific reasons for the wait times specified.

A terminal assumes that an RCCOW service request was lost by the DAMA controller, if a CCOW Acknowledgment message is not received within three frames or 4.2 seconds. When this happens, the terminal selects a random number between 1 and 20 and waits that number of frames before continuing with the procedures below. The RCCOW is automatically retransmitted once. Further retransmissions require the service request to be reentered. The delay in retransmission is a function of the precedence of the RCCOW and the frame used in the initial transmission of the service request. General frame precedence is established by the DAMA controller and forwarded to all terminals in the Precedence Cutoff field of the master frame and in the RCCOW Assignment field of the CCOW. Additional automatic retransmission of the service request is based on the following:

A. Frame and Initial RCCOW Precedence Equal. If the frame and service request precedence were equal for the initial transmission, after the random wait described above, the request is retransmitted in the next frame where the frame precedence is equal to or greater than the service request precedence.

B. Initial RCCOW Precedence Greater Than Frame. If the service request precedence was greater than the frame precedence for the initial service request, after waiting the random number of frames described above, the next 8 frames are checked. If a

frame of equal precedence to the service request is found, the request is transmitted. If an equal precedence is not found, the request is transmitted thereafter, in the first frame in which the service request precedence is equal to or greater than the frame precedence.

After this first retransmission, the terminal will look for a CCOW acknowledgment in the third frame following transmission. If an acknowledgment is not received at that time, the RCCOW service request will be maintained in a queue for a random number of frames (1 to 20). If service request acknowledgment is not received within the random number of frames, the RCCOW is removed from the queue. Further transmissions of the service request require reentry. If the service request receives an acknowledgment before the random number of frames concludes, the call is processed.

The delay in processing the second transmission of the service request is noted in Table B-2 for conditions in which the frame precedence and initial RCCOW is equal and when frame precedence is less than RCCOW. The delays shown assume no collision and the first available frame, noted in 3, below, met precedence requirements. Each delay noted in the table is explained as follows:

Table B-2 25-kHz Call Set-up Delay*

REASONS for DELAYS	DELAY (seconds)
Delay awaiting call acknowledgment	4.2
Delay while in queue	1.4 to 28
Delay to find proper frame precedence	1.4
TOTAL	7 to 34

* no collision and frame precedence match

1. A 3-frame delay before the terminal notes that a call acknowledgment was not received and assumes that the service request was lost, or 4.2 seconds.

2. A delay of 1.4 to 28 seconds for the time the initial service request is maintained in a queue following the point that call acknowledgment should have been received. It is at the completion of this time that the terminal takes action to retransmit.

3. A delay of 1.4 seconds awaiting next frame. Note that this assumes the next frame has a precedence equal to the call precedence. Additional delays could be experienced if there is not a match.

APPENDIX C

REFERENCES

The following references were used in the preparation of this tutorial:

A. MIL-STD-188-181, *Interoperability Standard for Dedicated 5-kHz and 25-kHz UHF Satellite Communications Channels*, 18 September 1992

B. MIL-STD-188-182, *Interoperability Standard for 5-kHz UHF DAMA Terminal Waveform*, 18 September 1992

C. MIL-STD-188-183, *Interoperability Standard for 25-kHz UHF TDMA/DAMA Terminal Waveform*, 18 September 1992

D. JTC3A Report 9300, *Tutorial on Satellite Communications with Emphasis on UHF TDMA/DAMA Systems*, Draft, 31 October 1991

E. JTC3A Final Report, *Benefits of 25 kHz TDMA/DAMA for UHF Satellite Communications*, 8 March 1992

F. DISA/JIEO CFS Briefing and Report, *UHF SATCOM DAMA Principles and Assessments of UHF DAMA Management and Control*

G. Joint Staff Memorandum, Subject: *Tasking Based on MILSATCOM Users Conference 93-1*, dated 10 September 1993.

H. *Joint UHF SATCOM DAMA Concept of Operations (CONOPS)*